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BOWLDER-PAVEMENT AT WILSON, N. Y.

BOWLDERS in till when groupt in an approximately horizontal plane and striated on their upper surfaces in a common direction constitute a bowlder-pavement.[1] Considerable attention has been given to such pavements in Scotland, especially by the Hugh Millers, father and son. In 1859, O. N. Stoddard described a fine example near Miami University, O., but no other American observations have come to my attention.[2] While engaged, last summer, in field work of the United States Geological Survey, I came upon another example, which seems worthy of record.

The village of Wilson is situated about twelve miles east of the Niagara River and half a mile from the shore of Lake Ontario. One of its main streets runs to the shore, where a short pier juts into the lake. There are longer piers a little farther west at the mouth of Twelvemile Creek. On this part of the lake coast the movement of shore drift is from west to east, and this movement is locally obstructed by the piers. West of the piers there is an accumulation of shore drift, and the land gradually encroaches on the lake. East of them the defect of shore drift deprives the shore of its natural protection, and erosion is exceptionally rapid. At the Wilson pier the bluff due

[1] This is the usage of the Scottish geologists. The term has been employed in another sense by J. W. Spencer; see explanation of plate, p. 775.

[2] Diluvial Striæ on Fragments in Situ, by O. N. STODDARD. Amer. Jour. of Sci., 2d Ser., Vol. XXVIII, pp. 227–228.

Unpublisht observations by H. L. FAIRCHILD and M. R. CAMPBELL indicate allied phenomena at Rochester, N. Y., and Cleveland, O.

to the attack of the waves is twelve to fifteen feet high and free from talus, and the section is fully exposed for a half mile to the east. The lower part of the bluff is composed of till, eight to ten feet being visible, and the base not seen. Above this is laminated clay, a deposit spread by the waters of the glacial lake Iroquois.

To casual observation the till appears to be a single continuous body, but more careful examination shows that there are two parts separated by a horizontal line between five and six feet above the surface of the water. Both tills are reddish-brown, but there is a slight difference in color, the upper inclining toward orange and the lower toward purple. At various points a bitter efflorescence was seen on the surface of the upper till, and this was not observed on the lower. Both tills are moderately supplied with pebbles and bowlders, the material of the larger fragments being chiefly sandstone and limestone of the subjacent Medina and contiguous Hudson River formations, and ranging in diameter up to about twenty inches. There are also crystalline erratics from a distance, and a few of these are several feet in diameter. Such larger bowlders were not seen in situ in the bluff, but occur here and there on the beach and in shallow water near the shore, where they have evidently been left by the erosion of the enclosing till.

Just at the top of the lower till bowlders are comparatively abundant, and such as are flat lie with their greater dimensions horizontal. Their upper surfaces form parts of a level line drawn across the bluff (Plate XIV), and it was their alignment which drew attention to the compound character of the till. So far as the upper till betrays structure, its lamination is approximately horizontal. Much of the lower till is somewhat definitely laminated, and the lamination is contorted. In some places there are irregular masses of gray till mingled with the red, the general arrangement being suggestive of structures commonly seen in the Archean complex.

Examination showed nearly all the bowlders at the plane of separation to be striated on their upper surfaces. The directions

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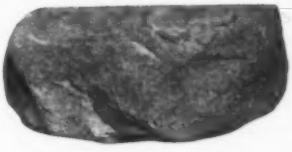

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BOWLDER-PAVEMENT

of striation were observed in the cases of ten bowlders in situ, and found to be substantially parallel. Nine ranged between S. 45° W. and S. 50° W., and the tenth was S. 55° W. The accompanying illustrations (Pl. XIV, Figs. 1, 2, and 3) show the upper faces of two of the bowlders and the side of one. It seems clear that after the deposition of the lower till it was over-ridden by a glacier moving toward the southwest. This is the general direction of striation on the bed rock of the region, but no observation was made in the immediate vicinity of Wilson.

All the bowlders strongly glaciated on their upper surfaces were found to have one diameter less than the others, and to lie in such position that the least diameter was vertical. So far as observed, bowlders without pronounced differences in their several diameters were not more strongly glaciated on the upper side than on other sides, although lying at the same level as the others.

To account for these peculiarities, as well as for the accumulation of bowlders at the summit of the lower till, the following explanation is offered: The glacier which deposited the upper till slowly eroded the lower till as it moved over it. When this erosion began to uncover a bowlder, differential pressures resulted. In Fig. 1 the horizontal line represents the upper sur-

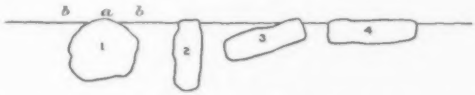

FIG. 1. Diagram illustrating theory of bowlder arrangement.

face of the till undergoing erosion, and 1 the discovered bowlder, projecting above the till at *a*. If the glacier were stationary it would mold itself plastically about this protuberance and press equally on *a* and *bb*, but as it is in motion and has great viscosity, the pressure is greater at *a* than at *bb*, and the differential pressure is not merely momentary, but continuous. It has the effect of a simple pressure on the bowlder at *a*, forcing it down into its plastic matrix, and as the erosion of the till continues,

the bowlder is steadily pusht downward. The erosion is thus rendered selective, the bowlders remaining as the fine material is carried away. The bowlders accumulated at the surface of the lower till are a residuum from the portion of the till which has been removed.

Combined with the vertical pressure at *a* is a horizontal pressure (from forward motion of glacier) tending to rotate the bowlder in its matrix. In the case of a rounded bowlder there may be rotation as long as it continues to be forced downward, but a flat bowlder eventually reaches an attitude of stability. If the longer diameter lies originally vertical or oblique (2 or 3, Fig. 1), there is a partial rotation bringing it to a horizontal position (4, Fig. 1), and rotation then ceases because the differential vertical pressure is applied to both edges of the rock, and any incipient rotation is checkt by increase of pressure on the rising edge. The horizontal attitude is thus stable, and a bowlder having once acquired it retains it as long as the process continues, being thereby enabled to receive thorough glaciation on its upper face.

If this explanation is correct, a bowlder-pavement records an epoch of local till erosion by a glacier. The epoch may be a mere episode interrupting a period of till deposition by the same glacier, or it may be a part of a stage of readvance following a long interglacial period. The demonstration of two tills at the Wilson locality does not by itself constitute an important contribution to the subject of the complexity of glacial history, for the removal of the upper part of the lower till has destroyed whatever evidence may have existed as to the length of time interval separating the two. The significance of the phenomenon can hardly be understood until it shall have been brought into relation with cognate facts from a broad field.

The observation may perhaps serve a more important purpose by directing attention to the possibility of gathering much information as to the direction and history of ice motion from the internal structure of till sheets. The second Hugh Miller not only found a body of information in bowlder-pavements, but

discovered that in certain Scottish and English tills the elongated fragments, large and small, are oriented in the direction of ice motion, so that he was often able from direct examination of the till to determine the direction of the ice current by which it was deposited.[1]

A bowlder-pavement, doubtless continuous with the Wilson, was seen at the lake shore, three miles west of the village, the plane of separation being two or three feet above the water level.

G. K. GILBERT.

EXPLANATION OF PLATE.

FIGS. 1, 3. Glaciated faces of bowlders from bowlder-pavement. × ½.

FIG. 2. Side of the bowlder represented in Fig. 1, showing even truncation of glaciated face. × ½.

FIG. 4. Till and bluff at Wilson, showing line of bowlders at horizon of bowlder-pavement. Sketch by H. H. Nichols, based on a photograph.[2]

[1] On Bowlder Glaciation, by HUGH MILLER, Proc. Roy. Phys. Soc. of Edinburgh, Vol. VII, pp. 156–189, 1884. This paper summarizes earlier literature, and is itself probably the most important contribution to the subject.

[2] The strand is thickly set with bowlders release from the till by wave erosion. For such accumulations J. W. Spencer, doubtless unaware that the term was pre-occupied, proposed the title "bowlder-pavement." In each case the term designates a residuum from erosion, the process being in one case glacial, in the other littoral. It chances the view, drawn to show one kind of bowlder-pavement, illustrates the other also.

GEOGRAPHIC RELATIONS OF THE TRIAS OF CALIFORNIA.[1]

Historical.—Triassic fossils were discovered in California by the State Geological Survey under J. D. Whitney; these were rightly recognized by Gabb[2] as being nearly related to the Upper Triassic Fauna of the Alps, and certain species were even looked upon as identical with European forms. This was the first discovery of marine Trias in the western hemisphere, and the third discovery outside of Europe, the first being that in northern Siberia by Keyserling,[3] the second that in the Himalayas of India, by Strachey,[4] and later described by Salter.[5] Nothing more was done with the Trias in America until the Survey of the Fortieth Parallel discovered it in the Star Peak range of Nevada, where Meek[6] thought he recognized some Californian species. Shortly after this Lower Trias was discovered in southeastern Idaho, by the Hayden Survey, and described by Dr. C. A. White;[7] no Californian species were found here, but this discovery proved the occurrence in the West of a Lower Triassic fauna like that of the Asiatic region.

The next publication on the Californian Trias was by E. von Mojsisovics in *Arktische Triasfaunen*,[8] in which some of Gabb's species are compared with ammonites from Siberia, and the relations of the American faunas to those of the Arctic-Pacific province are discussed.

[1] Published by permission of the Director of the United States Geological Survey.

[2] Palæont. Calif., I, pp. 19–35.

[3] Bull. phys.-math. de l'Acad. Sci. de St. Petersbourg, Tome V, No. 11.

[4] R. STRACHEY: Quart. Jour. Geol. Soc. (London), Vol. VII, pp. 242–310, 1851.

[5] J. W. SALTER (and H. F. BLANFORD), Palæontology of Niti in the Northern Himalayas, 1865.

[6] Geol. Exp. Fortieth Parallel, Vol. IV, Part I, 1877.

[7] U. S. Geol. and Geol. Surv. Terr., Vol. XII, An. Rep., Part I, 1883.

[8] Mém. Acad. Impér. Sci. St. Petersbourg, VII Ser., Tome XXXIII, No. 6, 1886.

Professor Alpheus Hyatt[1] next undertook a revision of Gabb's work, visiting the original locality and adding largely to the faunal list, and especially to our knowledge of the stratigraphic distribution of the species.

In 1892 the writer's attention was called by Dr. H. W. Fairbanks to a bed of ammonite-bearing limestone near Pitt River in Shasta county; on examination the fossils proved to be of Upper Triassic age. This locality was soon afterwards visited by the writer, who spent the field season of 1893 at work in that region. This work added over fifty species to the known fauna, chiefly of Karnic age, and nearly related to characteristic species from the Tyrolean Alps.[2] The writer has since spent a good part of the field seasons of 1895 and 1898 collecting in that region, and has added greatly to the fossil list, especially of the Ceratitidæ and the Tropitidæ, bringing out even more strongly the relations with the Alpine Trias. A part of these results has already been published.[3]

The latest paper on the Triassic stratigraphy of California is by Dr. E. von Mojsisovics,[4] who, on the basis of communications of Professor Hyatt and the writer, and a suite of fossils sent him by the writer, compares at considerable length the American to the European Upper Triassic faunas.

The accompanying table is based on that published by the writer in *Classification of Marine Trias*, but revised and brought up to date so as to include the stratigraphic work of the past two years, and to give a satisfactory basis for the correlation of marine Triassic sediments for all known regions. Of course it is only tentative, merely the opinions of several men engaged in this study; but the wide distribution of such zone faunas as

[1] Bull. Geol. Soc. Amer., Vol. III, "Jura and Trias at Taylorville, California," pp. 397–400.

[2] Jour. Geol., Vol. II, No. 6, 1894, "The Metamorphic Series of Shasta county, California, and Jour. Geol., Vol. III, No. 4, "Mesozoic Changes in the Faunal Geography of California."

[3] Jour. Geol., Vol. IV, No. 4, "Classification of Marine Trias."

[4] Denksch. K. Akad. Wiss. Wien. (Math. Nat. Kl.), Bd. LXIII, 1896, "Beiträge z. Kennt. d. Obertriadischen Cephalopoden Faunen des Himalayas.

CORRELATION OF MARINE TRIASSIC SEDIMENTS.

Series	Stage	Substage		Zone Fossil	Mediterranean Region	Oriental Region	Arctic-Pacific Region	American Region
Bajuvaric	Rhaetic		22	*Avicula contorta*	Koessen Beds			
	Noric	Sevatic	21	*Sirenites argonautæ*	Noric Limestone of Hallstädt / Balia-Maden in Asia Minor	*Halorella* beds of the Pamir; Himalayan Noric limestone	*Monotis* beds of Rotti; *Stenarcestes* beds of New Caledonia	*Pseudomonotis* beds ? of Peru; Swearinger slates, Californian; Hosselkus limest'ne (of Queen Charlotte Islands)
			20	*Pinacoceras metternichi*				
		Alaunic	19	*Cyrtopleurites bicrenatus*				
		Laciacic	18	*Cladiscites ruber*				
			17	*Sagenites giebeli*				
Tirolic	Karnic	Tuvalic	16	*Tropites subbullatus*	Sandling beds	Himalayan Karnic limestone	*Daonella* beds of Rotti; *Juvavites* beds of Tonquin, China	with *Subbullatus* and *Trachyceras* faunas; Halobia beds (Trias)
		Julic	15	*Trachyceras aonoides*	Raibl beds			
		Cordevolic	14	*Trachyceras aon*	St. Cassian beds			
	Ladinic	Longobardic	13	*Protrachyceras archelaus*	Wengen beds		Nipon beds of Japan	Pitt Shales of Shasta County, (Star Peak beds of Nevada)
		Fassanic	12	*Dinarites avisianus*	Marmolata beds			
			11	*Protrachyceras curionii*	Buchenstein beds			
Dinaric	Anisic	Bosnic	10	*Ceratites trinodosus*	Upper Muschelkalk	*Ptychites rugifer* beds of the Himalayas	*Daonella* beds; *Posidonomya* beds (Spitzenbergen); Beds of Russkij and Olenek	California (Nevada)
		Balatonic	9	*Ceratites binodosus*	Lower Muschelkalk	*Sibirites prahlada* beds of the Himalayas		
	Hydaspic		8	*Stephanites superbus*		Upper *Ceratite* limestone of the Salt Range		
Scythic	Jakutic		7	*Flemingites flemingianus*	Zone of *Tirolites cassianus*	*Ceratite* limestone of the Salt Range; *Subrobustus* beds of the Himalayas	Olenek beds of Siberia	*Meekoceras* beds of ? Idaho (Santa Ana limestone of California)
			6	*Flemingites radiatus*				
			5	*Ceratites normalis*				
	Brahmanic	Gandaric	4	*Proptychites trilobatus*	Werfen beds of the Tyrolean Alps / *Tirolites* beds of Djulfa in Armenia	*Ceratite* marls of the Salt Range	Beds of Ussuri and Russkij	*Ceratite* limestone of Inyo County, California
			3	*Proptychites lawrencianus*				
			2	*Gyronites frequens*		Lower *Ceratite* limestone of the Salt Range		
		Gangetic	1	*Otoceras woodwardi*		*Otoceras* beds of the Himalayas		

those of the *Meekoceras* beds of the Lower Trias, of the *Trachyceras* and *Tropites subbullatus* faunas of the Tirolic series, and of the *Pseudomonotis* beds in the Arctic-Pacific region, makes interregional correlation a much easier task.

The nomenclature of the table is that of Diener, Waagen and E. von Mojsisovics,[1] with the exception that *Ladinic* has been substituted for *Noric*, and *Noric* instead of *Juvavic*, the controversy between Bittner and v. Mojsisovics having been settled by a committee of the leading Austrian geologists[2] agreeing to make this change, and by this recommendation being in part accepted by v. Mojsisovics. It is immaterial to American stratigraphers which names are used, but since the Alpine Trias is the type of the marine formation of this age we must use the original formational names given by the Austrian geologists, and in the original sense. It is, therefore, a cause for congratulation that the committee report has been so widely accepted, and for regret that E. von Mojsisovics is still inclined to cling to his new term *Juvavic* for the Hallstadt beds which he formerly called *Noric*.

LOWER TRIAS.

The Santa Ana limestone.—The first Lower Trias recognized in California was found by Dr. H. W. Fairbanks in a hard black siliceous limestone on the west slope of the Santa Ana range, Orange county, California. The fossils were submitted to the writer, and proved to be: a trachyostrachan ammonite, not otherwise determinable, an undetermined brachiopod, and *Pseudomonotis* aff. *clarai*. The ammonite makes the Mesozoic age probable, and the pelecypod makes almost certain the Lower Triassic age, for *Pseudomonotis clarai* is diagnostic for the Werfen beds, upper part of the Alpine Lower Trias. It seems quite possible that this formation in California may be the connecting link between the Mediterranean and the Oriental regions, for the furthest known eastward extension of the Mediterranean Lower Trias,

[1] Sitzungsberichte k. Akad. Wiss. Wien. Bd. CIV. Abth. I. Dec. 1895. Entwurf einer Gliederung der Pelagischen Sedimente des Trias-Systems.

[2] Zur Ordnung der Trias-Nomenclatur. Wien 1898.

that of Djulfa in Armenia, is still of Alpine type, with *Tirolites*? and *Pseudomonotis* conf. *clarai*. The connection that existed in Permian time between India and eastern and southern Europe, through Asia Minor, seems to have been cut off in the Lower Trias. But these faunas are too meager for this to be much more than mere speculation.

	Permian	Lower Trias			Middle Trias	Upper Trias
		Brahmanic		Jakutic		
		Gangetic	Gandaric			
						Mediterranean and California
Lytoceratidæ, *Nannites*		Himalayas ×				×
Pinacoceratidæ, *Clypites*?			Salt Range ×			
Meekoceratidæ, *Koninckites*		Himalayas ×	Salt Range ×	Salt Range, rare ×		
Meekoceratidæ, *Meekoceras*		Himalayas ×	Salt Range ×	Mediterranean, Idaho ×	Salt Range ×	
Meekoceratidæ, *Kingites*		Himalayas ×	Salt Range ×	Olenek and Salt Range ×		
Meekoceratidæ, *Gyronites*?			Salt Range ×	Salt Range, Olenek ×		
Ptychitidæ, *Xenaspis*	Salt Range ×	Himalayas ×	Usuri ×		Himalayas × ?	
Celtitidæ, *Dinarites*				Mediterranean Salt Range Arctic ×	×	
Tropitidæ, new genus						

The Ceratite limestone of Inyo county.—In 1896 Dr. C. D. Walcott discovered some ammonite-bearing limestones in Inyo county on the east side of Owens' valley ten miles east-northeast of Lone Pine, two or three miles south of the Eclipse mill,

and about 3000 feet up above the mill, on the trail from Independence ever the Inyo range to Saline valley. The fossils submitted to the writer were badly crushed and distorted, owing to the partial metamorphism that the limestone has undergone, so that they were not in condition for description of genera and species, nor for identification with known species. But the septa permitted the identification of several genera of ammonites with considerable certainty; none of them were higher than the ceratite stage, and some retained simple goniatitic septa, a combination which, in itself, would point to Lower Triassic age, even if all the genera were new. The genera determined were all ammonites, no others being recognizable. The list is given on page 780, showing the range and occurrence of these genera.

In the above list it will be seen that most of the genera are confined to the Lower Trias, or Scythic series, of India, and that while most of them range through the Brahmanic and Jakutic stages, they nearly all reach their greatest development in the Brahmanic, and are rare outside of it. Thus it is probable that the Ceratite limestone[1] of Inyo county belongs to the Brahmanic. Another bit of evidence is the occurrence of some undetermined ammonites not included in the above list, resembling *Otoceras*, which in Armenia occurs in the highest Permian and in the Himalayas in the lowest Trias, only a few feet above the highest *Productus* beds, the top of the Palæozoic.

This fauna is wholly unlike anything in Europe, or indeed anywhere else outside of India, but it resembles that described from the Salt Range by Waagen,[2] and from the Himalayas of India, and Ussuri Bay by Diener.[3] Some years ago it was pointed out by Mojsisovics in *Arktische Triasfaunen* that the Lower Trias of Idaho was closely related to that of the Arctic-Pacific region, although no certain comparison could be made. In the Californian fauna we have the best means of comparison

[1] So-called, because of the prevailing ceratitic type of the ammonites.

[2] Pal. Indica. Salt Range Fossils. Fossils from the Ceratite Formation.

[3] Pal. Indica. Ser. XV. Himalayan Fossils. And *Mém. Com. Géol. St. Petersbourg*. Vol. XIV. No. 3. Triadische Cephalopodenfaunen der Ostsibirischen Küstenprovinz.

with the Indian ammonites, through the monographs of Waagen and Diener. We may, then, assume as certain a connection of the Californian waters with the Oriental region during Brahmanic or Jakutic time, forming the *Arktis* of Mojsisovics, and a separation from the Mediterranean Triassic sea or *Thetys* of Suess. How intimate this connection was we cannot know until material good enough for the identification of species is found.[1]

The danger of inferring separation of provinces on the basis of too few fossils is shown by the following diagram, illustrating the relations of the Lower Trias of the Salt Range with that of the Himalayas, according to Diener.[2]

<table>
<tr><th>Himalayas</th><th>Salt Range</th></tr>
<tr><td>Muschelkalk</td><td>Upper Ceratite limestone</td></tr>
<tr><td>Subrobustus beds</td><td>Ceratite sandstone</td></tr>
<tr><td rowspan="2">Almost unfossiliferous</td><td>Ceratite marls</td></tr>
<tr><td>Lower Ceratite limestone</td></tr>
<tr><td>Otoceras beds</td><td>Unfossiliferous</td></tr>
<tr><td colspan="2">Permian</td></tr>
</table>

The Permian faunas are closely related in both, and that of the Subrobustus beds is, in part, identical with the fauna of the Ceratite sandstone, while between these two horizons each province has unfossiliferous beds corresponding to strata rich in ammonites in the other. It is not, therefore, a justifiable infer-

[1] The writer hopes during the season of 1899 either to visit this locality in person, or to send some of his students there.

[2] Mém. Géol. Surv. India. Ser. XV. Himalayan Fossils. Vol. II. Part I, p. 177.

ence that they were connected in Permian time, and separated after that until Jakutic time.

Tirolites and other members of the Tirolitinæ are conspicuously lacking in the Indian region, and this is true also of the Inyo beds. On the other hand *Dinarites* is entirely lacking in the Lower Trias of the Himalayas, and in the Salt Range below the Ceratite sandstone of the Jakutic, the species described as *D. minutus* Waagen, from the Ceratite marls, having turned out to be a *Ceratites*. And since the Dinaritinæ are known in the Lower Trias of the Mediterranean region, the Inyo fauna seems to have been intermediate between that and the Indian, although much more intimately connected, during the Brahmanic stage, with the Oriental region.

Gabb[1] cites *Goniatites lævidorsatus* Hauer from a locality thirteen miles north of Owens' Lake, from the foothills on the east side of the valley. E. von Mojsisovics[2] says that this ammonite is not Hauer's species, and not even in the same genus with it, *Celtites*, but belong to the group of *Ceratites obsoleti*, subgenus *Danubites*, chiefly characteristic of the Lower Trias. It seems, therefore, that the credit for the discovery of this formation in California must be given to the State Geological Survey under Whitney.

MIDDLE TRIAS

Of the faunal relations of Middle Trias little is to be said, because undoubted fossils of this age are not yet known in the state, nor, indeed, anywhere in America. The writer[3] has described a series of siliceous slates that probably belong in part to the Muschelkalk, but the evidence is merely stratigraphic, the known fossils being too poor to be of any use. The occurrence, at Silverthorn's Ferry on Pitt River, of a number of indeterminable ammonites, one of which resembles *Ptychites*, holds out the hope of future decisive discoveries. It seems likely, too,

[1] Pal. Calif., Vol. I, p. 21.

[2] Arktische Triasfaunen, p. 20.

[3] Jour. Geol.; Vol. II., 1894, No. 6. The Metamorphic Series of Shasta county, California.

that a part of the Star Peak beds of Nevada may eventually be shown to belong here, as Professor Hyatt has long claimed, but as yet the evidence is not convincing.

UPPER TRIAS.

The Upper Trias of the Genessee valley, Plumas county, was discovered and described by the Whitney Survey; its fauna is decidedly Alpine in character, although all the species thought by Gabb to be identical with European forms have since been shown not to agree with them. Since that time Professor Hyatt[1] has visited this locality, and has added greatly to the fossil list, some of the newly discovered ammonites being doubtfully referred to Alpine species.

The Upper Trias of Squaw creek, Shasta county, was discovered by Dr. H. W. Fairbanks, who called the writer's attention to the locality. The writer has since spent a good part of three field seasons in collecting fossils, and in studying the stratigraphy of that region; part of the results of this work has already appeared in the JOURNAL OF GEOLOGY.[2] In the papers referred to the most important species have been listed, although later field and museum study has changed the list considerably, adding many new ones, and dropping several. The fauna contains a large number of *Trachyceras* (subgenus *Protrachyceras*), *Clionites*, *Arpadites*, *Polycyclus*, *Sirenites*, *Tropites*, *Eutomoceras*, *Juvavites*, *Sagenites*, *Nannites*, *Miltites*, *Arcestes*, *Halobia*, etc., of decidedly European type. Dr. E. von Mojsisovics is of the opinion that several of these may be identical with species characteristic of the Tyrolean Alps. The greater part of the fauna belongs to the Karnic stage, zone of *Tropites subbullatus* Hauer, which characteristic ammonite of the Sandling beds is also present in great abundance in the Squaw creek limestone, showing all the varieties known in the Alps.

In the papers cited above the writer has called attention to the occurrence of species *Trachyceras* along with *Tropites subbul-*

[1] Bull. Geol. Soc. Amer., Vol. III, pp. 397–400.

[2] Vol. II, 1894, No. 6; Vol. III, 1895, No. 4; Vol. IV, No. 4, 1896.

latus Hauer, *T. torquillus* Mojs., *T. Telleri* Mojs., and many others characteristic of the Tuvalic substage. In the Hallstadt beds of the Tyrol no such association as this is known; the *Trachycerata* do not occur higher up than the Julic substage, zone of *Trachyceras aonoides*, nor does the Subbullatus fauna appear below the Tuvalic. It is, therefore, a question as to whether the Julic fauna survived longer here than elsewhere, or whether the *Tropites subbullatus* fauna reached here earlier, in middle Karnic time. There is not yet enough evidence to decide this, but it all points to the latter alternative. The *Tropites* fauna is an immigrant fauna wherever known, appearing suddenly without local ancestors in the Alps, the Himalayas, and in California, in the upper part of the Karnic stage; thus it may be that its occurrence in California marks an earlier appearance, for it was probably endemic in the American region. In addition to this, the *Trachycerata* associated with the Subbullatus fauna all belong to the subgenus *Protrachyceras*, which is supposed to be characteristic of a lower horizon than *Trachyceras* itself, which genus has recently been found in the Upper Karnic of the Himalayas. Further, the Subbullatus fauna did not all reach California at the same time, *Homerites semiglobosus* Hauer, not appearing here until all the *Trachyceras* fauna, and most of the *Tropites*, with which it is associated in the Alps, had become extinct.

We have in this occurrence an interesting study in homotaxis; the *Trachyceras* fauna is homotaxial all over the world, so is the Subbullatus fauna, and yet their occurrence together proves that neither fauna was synchronous in its appearance in various parts of the earth, and that even the order of appearance of the two faunas is not the same in all regions.

The most comprehensive review that has appeared on the faunal geography of the Upper Trias is the chapter by Dr. E. von Mojsisovics, "Die Meere der Trias-Periode,"[1] in which all that is known of the distribution and relations of faunas of this period is given, and several pages devoted to the western Ameri-

[1] Denkschriften d. K. Akad. Wiss. Wien, Bd. LXIII, 1896, "Beitr. z. Kenntniss d. Obertriadischen Cephalopoden Faunen des Himalayas."

can Trias, based on the published writings of Gabb, Meek, Hyatt, Whiteaves and the writer, and upon personal communications from Hyatt and the writer. Mojsisovics here takes the view that the occurrence together of the Subbullatus fauna and *Trachyceras* in India and California shows a survival of the latter group beyond its time elsewhere; this is more likely true of India, where the survival consists of single species of genuine *Trachyceras*, but in California the fauna is almost too large to be a survival.

The most interesting fact brought out by a comparison of the Upper Trias of California with that of India and the Alpine Mediterranean region is its near relationship with the latter, most genera and many species being common to the two regions. On the other hand, not many genera and no species are now known to be common to California and India; this is contrary to what we should expect, knowing that during the Lower Trias California was closely connected with India, as shown by community of genera and possibly of species, and also that during this same time neither India nor California was closely connected with the Mediterranean Triassic sea. Great changes in physical geography must have taken place about the end of Lower Triassic time, of which we have a partial record; during the Muschelkalk several species are common to the Indian, the Arctic-Pacific, and the Mediterranean regions, thus showing an opening of connection between regions that before were separated.

This relationship of the Californian to the European faunas persists until after the middle of the Jurassic formation, when the Boreal fauna comes in; towards the end of the Lower Cretaceous the connection with India is again established.

It is hard to see how anyone that has studied the changes of faunal geography undergone by the western American region since Paleozoic time could believe in the permanency of the oceanic basins as they now exist. These shifting faunal relations can only mean rising and sinking of continental margins, cutting off and facilitating intermigration, alternately aiding and obscuring interregional correlation. JAMES PERRIN SMITH.

THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. I.

THE area of igneous rocks in Eastern Massachusetts, especially in Essex county, has been, as the late Geo. H. Williams said, "more discussed than any other similar region of the continent." But, while it is the subject of a considerable literature, no petrological study of the region has been made. A few investigators, notably Wadsworth and J. H. Sears, have described the rocks, but there has been little or no attempt to coördinate the results and to compare this region with other analogous petrographical provinces, although its resemblance to that of Norway has been noted by Rosenbusch, Brögger and others. It is with the aim of supplying this deficiency that these pages are written.

I have visited the region of Essex county several times and collected a large number of specimens from the various localities, so that my collections are fairly representative of the different types, and my knowledge of their occurrences and relationships sufficient to justify me in undertaking the present investigation. This paper will deal with the subject in a purely petrological way, since the general geological, structural and stratigraphical features are far too complex to be unraveled in occasional visits such as mine were. A number of occurrences of dike and other rocks which merit a more detailed description than is here possible will be published separately, probably, in the *American Journal of Science*.

I would express my sense of deep obligation to Mr. J. H. Sears, of Salem, who has made this region an object of study for many years and whose acquaintance with it is unequaled. He has been most cordial and liberal in giving me specimens which it would have been difficult for me to obtain otherwise, and has encouraged me most generously in undertaking the present investigation.

While the general geology of the region lies outside the scope of the present paper, yet it will be not amiss to give a sketch of its chief features. The igneous rocks of Essex county extend along the coast from Lynn to the New Hampshire line, and inland for a distance of about five to fifteen miles, covering an area of about 342 square miles. To the south igneous rocks of similar character, and probably genetically related, are met with in the Boston Basin, but this paper does not include them. In Essex county they form a long ridge "extending in a northeasterly direction until cut off by the sea. To the northwest and to the southeast of this extended axis we have rocks of a less crystalline character verging upward into distinctly sedimentary deposits."[1] The igneous rocks have broken through and are later than pre-Cambrian and Lower Cambrian strata, blocks of which, often highly metamorphosed, are met with at many points within the igneous area.[2] The igneous rocks are chiefly granites, quartz-syenites, syenites, nepheline-syenites, essexites, diorites and gabbros, cut by numerous dikes, and with later flows of rhyolite. According to Sears[3] these are all pre-Carboniferous. A geological map of Essex county, prepared by Mr. Sears, and published by the Essex Institute in 1893, has lately (1897) been revised by him[4] and will be referred to frequently.

PETROGRAPHY.

In the description of the rocks the ideas as to classification generally prevailing in this country will be followed, the age distinction being ignored, and the rocks grouped according to structure and chemical and mineralogical composition. The separation of the dike rocks is largely for convenience and involves no assumptions as to the question of the "Ganggesteine." A number of chemical analyses will be given, and the descrip-

[1] N. S. SHALER. 9th Ann. Rep. U. S. G. Surv., p. 542, 1889.

[2] J. H. SEARS, Bull. Essex Inst., Vol. XXII, 1890.

[3] SEARS, Bull. Essex Inst. Vol. XXVII, p. 112, 1895.

[4] Bull. Essex Inst., Vol. XXVI, 1894, and *ibid*, Vol. XXVII, 1895.

tions will be followed by a general discussion of the results and a comparison of this region with others of similar character.

Granite. — The rocks which belong in this class and which are the granitites of Rosenbusch, have been described by Wadsworth,[1] Shaler[2] and Sears.[3] They are very abundant in the region, covering large areas at Rockport, Gloucester, Manchester, Beverly, Essex and elsewhere, having a general northeast-southwest trend.

The specimens in my possession from these localities are all hornblende-granites containing more or less biotite. The structure is in general typically granitic, a porphyritic development of the feldspar being rare. They are quite coarse-grained, the texture being fairly uniform in the various specimens. Fine-grained forms are less abundant and occur on the borders, as will be described later. In color they are usually light mottled gray (Rockport, west Gloucester, Manchester), but often yellowish (Bay View, Eastern Point), or pink (Wolf Hill, Marblehead Neck), these last two being due to incipient decomposition. The granite of Bass Rock is darker and greenish, forming apparently a transition to the augite-quartz-syenite.

The quartz is often dark and smoky. The feldspars are of the usual light shades, with good cleavage, being salmon-colored only in the specimens from Wolf Hill. Hornblende and biotite are scattered not very abundantly through the mass in black irregular spots. These are the principal minerals seen with the naked eye, but at the quarries of Rockport and elsewhere a large number of accessories have been found, including danalite, fayalite, epidote, zircon, magnetite, apatite, fluorite, and others.

In the area about Rockport pegmatitic veins are not uncommon, made up of coarsely crystalline feldspar and quartz, the latter being occasionally amethystine. The granite, especially of Cape Ann, is largely split by joint planes, and also shows a strong tendency toward rifting. This has been investigated

[1] WADSWORTH, Proc. Bost. Soc. Nat. Hist. Vol. XIX, p. 311, 1878

[2] SHALER, 9th Ann. Rep. U. S. G. Surv., p. 605, 1889.

[3] SEARS, Bull. Essex Inst., Vol. XXVI, 1894.

very fully by Shaler.[1] Judging from the evidence of strain revealed by the microscope the rifting (and possibly the jointing in part) is largely due to dynamic action subsequent to the consolidation of the mass.

In thin sections are seen the following minerals; orthoclase, albite, microcline, hornblende, glaucophane, biotite, pyroxene, magnetite, zircon, apatite, and allanite.

The quartz is highly xenomorphic, being usually interstitial. In some cases (Bass Rock, Rocky Neck at Gloucester) it also occurs in small rounded anhedra, scattered through feldspar areas. A brecciated structure at the borders of the larger quartzes is not rare, and is associated with an undulatory extinction. Mineral inclusions are few, and are only zircons. Gas and liquid inclusions, the latter carrying a movable bubble, are quite abundant though small, and occur in streaks.

The alkali-feldspars are varied and deserve more extended study than the scope of this paper allows. They are chiefly orthoclase and albite, which are almost always intergrown so as to form highly typical microperthites and cryptoperthites. In general they are closely similar to those described by Brögger[2] and Ussing[3] from Norway and Greenland syenitic rocks, and their figures would answer for forms seen here. Cryptoperthitic development is relatively scarce, the majority being perthitic on a fairly large scale. Microcline also is not rare, but less abundant than the preceding. This and the orthoclase are apparently rich in soda. The feldspars are apt to be rather cloudy and dusty with decomposition products, and they often show a brecciated border and undulatory extinction. Inclusions of apatite and zircon are rare. A very little albite-oligoclase is seen in a few sections, showing well-developed twinning lamellæ.

Hornblende, the chief ferromagnesian mineral, is usually xenophorphic, crystal planes being seldom seen. It is in gen-

[1] SHALER, 9th Ann. Rep. U. S. G. Surv., pp. 583–588, 602–605, 1889.

[2] W. C. BRÖGGER, Zeit. Kryst., Vol. XVI, pp. 521–560, 1890, Pls. XXII, XXIII

[3] USSING, Medd. om Grönland, Vol. XIV, pp. 5–101, 1898, Pls. I, II, III.

eral olive-green and highly pleochroic; **c** = dark olive-green, **b** = dark greenish-brown, **a** = yellowish-green. The absorption is **c** > **b** > **a**. The extinction angle **c** / \ *c* is high, about 29° having been observed in sections cut nearly parallel to (010). In certain specimens, notably those from Eastern Point (Gloucester) and Magnolia, a bluish hornblende occurs not only as separate crystals, but as patches in the green hornblende, and is also found forming a fringe on the ends of large crystals of this mineral. This occurrence is somewhat analogous to that described by Cross[1] in a dike in Colorado, where he regards the blue hornblende as secondary. His dike was much decomposed, while these granites are quite fresh; but it seems probable that here also part of the blue hornblende is secondary. As will be seen later, they are quite common in the region, and in many cases are undoubtedly primary. Inclusions in hornblende are not abundant, a few grains of magnetite, allanite, zircon, and apatite having been seen. The green hornblende often yields a secondary brown biotite on decomposition.

Biotite is a very common constituent, the greater part being primary. The granite near Manchester, represented by specimens from several quarries, is essentially a biotite-granite, hornblende being absent. In the majority of occurrences, however, the biotite accompanies hornblende, and is present in less amount. Two varieties are found. One is very pale green, with rather weak pleochroism, the colors being almost colorless and delicate apple-green. This is probably to be referred to the cryophyllite discovered by Cooke,[2] and investigated by Clarke and Riggs.[3] The other, which is more abundant, is darker greenish-gray, and shows stronger pleochroism; a deep, almost opaque, greenish-gray and a pale olive-green. Sections parallel to the base show in convergent light a marked opening of the optic axes. This biotite is referred to lepidomelane (annite), but Clarke's researches have shown that several varieties exist.

[1] Cross, Am. J. Sci., Vol. XXIX, p. 359, 1890.

[2] J. P. Cooke, Am. J. Sci. (2), Vol. XLIII, p. 217, 1867.

[3] F. W. Clarke, Am. J. Sci. (3), Vol. XXXII, p. 358, 1886.

Both biotites are notable for their poverty in MgO, which will be discussed later. They frequently show signs of alteration, accompanied by the development of magnetite grains, and their laminæ are often bent and distorted.

Secondary biotite occurs in most of the less fresh specimens, of a chestnut-brown color and highly pleochroic. It forms small flakes arranged perpendicular to or in fan-shaped aggregates along the edges of hornblende crystals, of which it is an alteration product. In the granite from the east side of Wolf Hill (Gloucester) are seen small clusters of small biotite flakes of an olive-green color and independent of hornblende, which are probably primary.

Pyroxene occurs in a few of the granites, most abundant in that of Marblehead Neck, though always in smaller amounts than the hornblende or biotite. It is a colorless diopside in stout, columnar, rounded crystals, and shows no noteworthy peculiarity. Occasionally, as at Trumbull's quarry, West Gloucester, it seems to be derived from hornblende, analogously to the often-observed "magmatic" alteration of hornblende in eruptive rocks. In some sections of granites which are not quite fresh the pyroxene is uralitized to some extent.

Magnetite is present in most of the granites, but very sporadically and in extremely small amount. Zircon and apatite are likewise present in most of the specimens, the former being the more common, while apatite is wholly absent in many.

Allanite occurs in granite from a quarry near the Lighthouse on Eastern Point and in that from Marblehead Neck. In the former it is included in hornblende, in the latter in biotite. The sections are rather long, with pointed ends, and the extinctions, either parallel or at angles up to 36°, show that the habit is tabular parallel to *a* (100). The color is deep brown, with strong pleochroism; $\mathfrak{a}$ = light yellowish-brown, $\mathfrak{b}$ = chestnut-brown, $\mathfrak{c}$ = very dark brown; $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. A zonal structure is common, the borders being lighter than the interior. Allanite was first observed in Essex county by D. M. Balch[1] in

[1] Am. J. Sci. (2), Vol. XXIII, p. 348, 1862.

1862 in the granite of Swampscott, was reported from several places in Maine and Massachusetts by Iddings and Cross,[1] while Sears[2] has added a number of localities to the list.

A small grain of pink fluorite was seen in the granite from Squam Light, and colorless grains in that from Pigeon Hill quarry, Cape Ann. I could identify no danalite, which Shaler speaks of as rare and resembling garnet in thin sections.

For chemical analysis a typical fresh specimen was chosen from the large pit of the Rockport Granite Co.'s quarry, a hornblende-biotite-granite; sp. gr. 2.618 at 18° C. There is given for comparison an analysis already published[3] of the riebeckite-granite of Quincy, described by T. G. White.[4]

	I	II		I	II
SiO_2	77.61	73.93	BaO	....	none
TiO_2	0.25	0.18	Na_2O	3.80	4.66
Al_2O_3	11.94	12.29	K_2O	4.98	4.63
Fe_2O_3	0.55	2.91	$H_2O(110°-)$	trace	....
FeO	0.87	1.55	$H_2O(110°-)$	0.23	0.41
MnO	trace	trace	P_2O_5	....	....
MgO	trace	0.04			
CaO	0.31	0.31	Sp. Gr.	100.54	100.91

I Hornblende-Granite. Rockport Cape Ann, Anal. H. S. WASHINGTON.
II Riebeckite-Granite. Quincy Blue Hills, Anal. H. S. WASHINGTON.

The analysis of the Rockport granite is a typical one, fairly rich in potash, but low in lime and iron oxides. It resembles that of the Quincy granite, but the latter is lower in silica and higher in iron oxides. Although the composition of the hornblende is unknown, yet as its amount is small, the mineral composition can be approximately calculated as below in Ia, the biotite being assumed to have the composition $(K_2H_4Fe_4)Al_2(SiO_4)_5$ as given by Clarke from an analysis by Riggs.[5] The composition of the Quincy granite calculated as already published is given in IIa.

[1] IDDINGS and CROSS, Am. J. Sci. (3), Vol. XXX, p. 108, 1885.
[2] SEARS, Bull. Essex Inst., Vol. XXVI, p. 189, 1894.
[3] H. S. WASHINGTON, Am. Jour. Sci. (4), Vol. VI, p. 181, 1898.
[4] T. G. WHITE, Proc. Bost. Soc. Nat. Hist., Vol. XXVIII, p. 128, 1897.
[5] CLARKE, Am. Jour. Sci. (3), Vol. XXXII, p. 360, 1886.

	Ia	IIa		Ia	IIa
Quartz,	35.5	30.2	Hornblende,	2.0	....
Orthoclase,	28.2	27.2	Riebeckite,	....	12.3
Albite,	32.0	27.7	Glaucophane,	....	2.0
Anorthite,	0.5	....	Accessories,	0.5	0.6
Biotite,	1.3	....			

Micrographic granite.—On reference to Sear's geological map of Essex county it will be seen that surrounding the granite areas and forming a zone between them and the areas of augite-syenite and diorite is a belt of micrographic granite. I have only a few specimens which represent this facies, the best being from Eastern Point, Gloucester, and from near Coy's Pond, Beverly, which were kindly given me by Mr. Sears. These closely resemble the granites, but are dark reddish-brown, finer grained and with less quartz visible. In thin sections they show much the same features as the granites proper. The minerals are the same, but quartz is less abundant. The difference is mainly in structure. In these rocks a micrographic intergrowth of feldspar and quartz is extremely common. The quartz here appears as small rounded spots extinguishing simultaneously in patches in the large feldspars. A similar micrographic structure is described by W. D. Matthew[1] in soda-granite from St. John, N. B. He states, however, that here this structure is best developed in the central parts of the mass and is lost at the edges.

In regard to the composition, while no analysis was made on account of the decomposed condition of the specimens, yet it seems probable, judging from the microscopical examination, that these micrographic granites are intermediate in composition between the granite proper and the augite-syenite, with a silica content of about 70.

Enclosures in granite.—In the granites of Essex county are found in abundance streaks (*Schlieren*) and rounded rock masses of darker color and of finer grain than the surrounding rock, which are also common in granite areas elsewhere. They show

[1] W. D. MATTHEW, Trans. N. Y. Acad. Sci., Vol. XIV, p. 205, 1895.

an evenly granular, granitic structure, varying in texture from moderately to very fine grained and compact. In color they vary correspondingly from light to very dark gray the most compact forms being the darkest. To the naked eye they show the same minerals as the granite, but the ferromagnesian constituents are more abundant. The contact with the surrounding granite is nearly always sharp and clear.

Under the microscope the same essential minerals are seen as in the granite and their habit is much the same, except that all is on a smaller scale. The alkali feldspars are quite similar, hornblende and biotite occur in all cases, the former being generally more abundant. It is usually green and only occasionally shows a bluish hue. In certain rather dark masses from the Pigeon Hill quarry, near Rockport, there is found a peculiar hornblende which occurs in bundles of long slender rods. In color it varies from colorless to pale bluish-gray, the latter shows brilliant polarization colors especially on the edges, and extinguishes obliquely, $\mathfrak{c} \wedge c$ being about 15°. The pleochroism is rather strong, $\perp c$ colorless or pale yellow, $\parallel c$ bluish or deeper yellow-gray, though occasionally it shows no pleochroism. It is apparently a variety of glaucophane. The biotite is also like that of the granites. It is sometimes secondary about hornblende, and in one specimen from Bay View it occurs about magnetite in brown flakes arranged radially. Colorless diopside is not abundant and often shows signs of alteration. Magnetite, while not abundant, is yet more common than in the granite. Zircon is common and in specimens from Pigeon Hill quarry forms well shaped but corroded crystals of considerable size, one being 1.5^{mm} long. Apatite is present as an accessory, but allanite was not observed.

SiO_2	67.35	MgO	0.03
TiO_2	0.60	CaO	0.55
Al_2O_3	15.05	Na_2O	4.42
Fe_2O_3	1.23	K_2O	6.08
FeO	4.76	H_2O (110°—)	0.16
MnO	0.05	H_2O (110°+)	0.17
			100.45

An analysis was made of a rather dark, fine-grained specimen from Pigeon Hill quarry, whose sp. gr. was 2.69 at 17° C. It is notably less siliceous than the granite, contains more iron and lime and higher alkalis, though the ratio of soda to potash remains about the same. From its analogy with the analysis of rocks described below it may be called a quartz-syenite. Owing to the uncertainty of the composition of the hornblende and biotite no exact calculation of the mineralogical composition is possible. A rough estimate gives albite 36, orthoclase 33, quartz 16, hornblende and biotite about 12, and magnetite, etc., 3 per cent.

Akerite (*augitic quartz-syenite*).—The rocks belonging in this class were first noticed by Wadsworth[1] in 1885 and were later described more in detail by Sears.[2] Rosenbusch[3] has expressed the opinion that these are related to the akerite type of syenites, a keen observation which my study of the rocks fully confirms. These rocks are found chiefly in the eastern part of Essex county, in Essex, Beverly, Manchester, Gloucester, and on Cape Ann. They lie between or around the granite areas, are connected with nepheline-syenites on the south, and have a general northeast-southwest trend. They appear to be almost as abundant as the granites.

Although Sears speaks of the megascopic characters as being extremely variable yet all the specimens collected by myself, as well as those given me by him, are fairly uniform. These show a granitic structure and are usually coarse-grained. The color even of the freshest specimens is greenish, which varies in shade from a dark greenish black to a light shade of greenish gray. They weather to a reddish color as Sears observed. The bulk of the rock is composed of feldspar which is of a deep greenish color, often fresh and with glistening cleavage surfaces, at other times dull and waxy. Quartz grains are present in varying amount, some specimens showing considerable while others

[1] WADSWORTH, Geol. Mag., 1885, p. 207.

[2] SEARS, Bull. Essex Inst., Vol. XXIV, 1892, and Vol. XXV, 1893.

[3] ROSENBUSCH, Mikr. Phys., Vol. II, p. 127, 1896.

contain very little, but it is never wholly absent. Black spots of augite are abundant and magnetite is seen here and there.

The microscope reveals the presence of the following minerals: quartz, alkali feldspar, diopside, hornblende, biotite, magnetite, apatite, and titanite. Quartz is not very abundant and is the last product of crystallization, occupying the interstices between the other minerals. It is undoubtedly primary, but the extinction is very often undulatory. The feldspars are mainly microperthitic intergrowths of orthoclase and albite, and resemble closely those of the granite. Microcline is rare. The feldspars are highly irregular as a rule, though some crystal outlines are seen against interstitial quartz. The boundaries between the adjacent crystals are generally zigzag or brecciated, indicating that the mass has been subjected to stresses. Some small albites show beautifully fine and clear twinning lamellæ. As they occur in such brecciated areas they may be supposed to be secondary. The feldspars very commonly show signs of alteration which is evidenced by a cloudy appearance, or when the crystal substance is clear by the cleavage lines and cracks being filled with a greenish decomposition product, the exact nature of which could not be determined.

The pyroxene occurs in scattered crystals of irregular outline. It is nearly colorless or a pale greenish-gray, without pleochronism but with high extinction angles. It is not infrequently uralitized on the edges, and carries inclusions of magnetite, apatite, and titanite. Primary hornblende of deep green or brownish colors is common in some specimens, notably in those from Poorhouse Hill, Beverly, and Cape Pond, Rockport. This is also intergrown with the pyroxene in parallel positions. Biotite is extremely rare or entirely wanting in these rocks, and when present is almost certainly secondary. Magnetite and apatite, occasionally in very long needles, are more common than in the granite. Zircon is present but is less abundant. Colorless titanite is quite common, usually in almost square sections with oblique extinctions. No nepheline was to be found in any of my sections, although Sears notes its presence. Its occur-

rence with quartz would be certainly very anomalous. Aegirite also, mentioned by Sears, was wanting in the material examined by me.

An analysis was made of a nearly fresh, typical specimen collected from a newly blasted mass on Prospect street, Gloucester. It is neither extremely light nor extremely dark in color, and seems to be an average sample of these rocks. Its sp. gr. was 2.612 at 17° C. For comparison there is given in II the analysis of an acid akerite from Norway.

	I	II		I	II
SiO_2	66.60	66.13	MgO	0.36	0.04
TiO_2	0.76	0.74	CaO	2.21	0.81
Al_2O_3	15.05	17.40	BaO	none	....
Fe_2O_3	1.07	2.19	Na_2O	4.03	5.28
FeO	4.42	....	K_2O	5.42	5.60
MnO	trace	0.13	H_2O	0.41	1.22
				100.33	99.54

I Akerite. Prospect street, Gloucester. H. S. WASHINGTON, anal.

II Akerite (porphyritic). Between Thinghoud and Fjelebua, Norway. MAUZELIUS, anal. BRÖGGER, Zeit. Kryst., Vol. XVI, p. 46, 1890.

It will be seen that this analysis, which closely resembles that of the enclosure in granite, except the higher lime, is essentially that of a basic granite or an acid syenite. In this case I adopt Brögger's scheme of classification,[1] and consider that the limit between the syenites and the granites lies at the silica content of the prevailing feldspars, which are here orthoclase with about 66 per cent. and albite with about 68. These rocks, therefore, I would class with the quartz-bearing augite-syenites, in accordance with Wadsworth, Sears and Rosenbusch.

That the rock belongs to an alkali magma is evident from its high alkali content ($K_2O + Na_2O = 9.45$), and its close parallelism with the *more acid* of Brögger's akerites is shown by comparison with the analysis in II. It must be noted, however, that this is an extreme type, and that the akerites as a group are more basic. Probably some of the darker and presumably

[1] BRÖGGER, Zeit. Kryst., Vol. XVI, p. 55, note, 1890.

more basic specimens, such as one from the railroad cut just north of the Manchester station, would correspond to them. The rather high lime is to be noted, but this is used up in the formation of pyroxene, leaving none for lime-soda feldspar, which, as the microscope shows, is not present.

Nordmarkite (*mica-hornblende-quartz-syenite*). — In Shaler's geological map of Cape Ann[1] there is indicated on both sides of Squam River an area of igneous rock, which is called diorite. Sears,[2] after a careful study of all the occurrences, came to the conclusion that they are not diorite but "phases of the augite-syenite rock," an opinion in which I concur. These rocks are far more limited in their distribution than the preceding, being found chiefly in Shaler's "diorite" area in West Gloucester and along the Squam River. I have specimens also from Hospital Point, Beverly, and from Salem Neck. They are light-gray fine-grained rocks, of granitic structure, looking like fine-grained diorite, composed of a white mass of feldspar, with subordinate quartz, thickly sprinkled with black specks of biotite and hornblende. The specimens from Hospital Point and Salem Neck are porphyritic through the presence of rectangular feldspar phenocrysts, from five to ten millimeters in length, and a few small quartzes.

They show under the microscope a granitic structure, though the quartz is less apt to be interstitial and usually forms small rounded spots in the feldspars, but is not pegmatitic as in the micrographic granite. The feldspars are alkali-feldspars, but do not show much tendency to microperthitic intergrowth. For the most part they are orthoclase or soda-orthoclase in simple crystals or Carlsbad twins. Albite is present in smaller amount, showing fine twinning lamellæ, with the extinctions proper to that mineral. In the specimens from Shaler's "diorite" area biotite is almost the only colored constituent. It forms small brown or greenish-brown, strongly pleochroic flakes, which are only rarely altered at the borders with development of magnetite grains. A

[1] SHALER, 9th Ann. Rep. U. S. G. Surv., Pl. LXXVII, 1889.

[2] SEARS, Bull. Essex Inst., Vol. XXV, 1893.

green hornblende is rare in these specimens and pyroxene seems to be entirely wanting. Magnetite, apatite and zircon are present in small amount. Aegirite, spoken of by Sears as often present, was not seen by me.

The specimens from Hospital Point and Salem Neck resemble these as far as the quartz and feldspars go, though these are finer in grain and microcline is more abundant. The biotite is also identical. A fresh, primary, greenish-gray pleochroic hornblende is abundant. Both minerals are much corroded. Magnetite and apatite are more abundant, zircon in about the same amount. These rocks are apparently transition forms toward a more basic variety, represented by specimens from Concord street, West Gloucester and from several points south of Shaler's area. The latter are darker in color, due to greater abundance of biotite and hornblende. They are like those just described in thin section except that there is less quartz, and hornblende and biotite are more abundant, the former predominating. While no plagioclase or nepheline was seen, they seem to be connecting phases with the diorites and essexites of the region near them.

For the analysis representing these quartz-syenites a specimen was chosen from the west end of Wolf Hill, northwest of Gloucester, which, although not far from the granite, was fresh and seemed to be representative of the rocks of Shaler's area. For comparison is given an analysis of nordmarkite from Norway.

	I	II		I	II
SiO_2	68.36	64.02	CaO	1.85	1.00
TiO_2	trace	0.62	BaO	....	....
Al_2O_3	16.58	17.92	Na_2O	3.97	6.67
Fe_2O_3	0.90	0.96	K_2O	5.27	6.08
FeO	3.24	2.08	$H_2O(110° -)$	0.18	....
MnO	trace	0.23	$H_2O(110° +)$	0.17	1.18
MgO	0.45	0.59		100.97	101.37

I Nordmarkite, Wolf Hill, Gloucester. H. S. WASHINGTON anal.

II Nordmarkite, Tonsenaas, North of Christiania. JANNASCH anal. BRÖGGER, Zeit. Kryst., Vol. XVI, p. 54, 1890.

The close resemblance of this analysis to those of the granite enclosure and the akerite is evident, the main difference being in the silica, while, like the akerite, it is richer in CaO and MgO than the enclosure. It also closely resembles the analysis of nordmarkite from the Christiania region, although rather more acid and with less alkalies. Since it corresponds to these in mineral composition the name of nordmarkite is justified, especially as the akerites are a more basic group, while the nordmarkites are essentially more acid in their characters and affinities. It may be noted *en passant* that here also, as in so many cases elsewhere, we meet with biotite and hornblende occurring in the more acid, while pyroxene occurs in the more basic, members of the same series.

Nepheline-syenite. — The rocks belonging here, first noticed by Streeter, have been described by several petrographers, of whom may be mentioned Kimball,[1] Wadsworth,[2] Sears[3] and Rosenbusch.[4] They are not abundant in the region and are confined to an area along the coast about eight miles long and much less wide, extending from Salem Neck to Gale's Point, Manchester, and including the islands in and near Salem Harbor.

These rocks, as is usual, are prone to variation so that there is much variety among the specimens, even from the small area of Salem Neck. Structurally they may be divided into two groups, a granitic and a trachytic, which correspond to the ditroite and foyaite of Brögger.[5] One or two representatives of Brögger's laurdalite-structure were found, but not in typical development. While the two main structural types shade into one another the foyaitic seems to predominate, or at least there is a strong tendency to foyaitic development.

The ditroites from Salem Neck, Great Haste Island and Mackerel Cove are not very coarse-grained rocks, of dull gray

[1] KIMBALL, Am. Jour. Sci. (2), Vol. XXIX, p. 67, 1860.

[2] WADSWORTH, Geol. Mag., 1885, p. 209.

[3] SEARS, Bull. Essex Inst., Vol. XXIII, 1891.

[4] ROSENBUSCH, Mikr. Phys., Vol. II, p. 185, 1896.

[5] BRÖGGER, Zeit. Kryst., Vol. XVI, p. 39, 1890, and also ERUPTGEST, der Krist. geb., Vol. III, p. 165, 1898.

color and granitic structure. The feldspar is white; nepheline gray or brownish, with occasional yellow or gray cancrinite and blue sodalite which is abundant in certain veins on Salem Neck and elsewhere. Biotite, hornblende and aegirite are common, but are very irregularly distributed. Often they are scattered uniformly through the mass, but again they are rare or else abundant, and any one may predominate to the exclusion of the others. Occasional small brown crystals of zircon are seen, often of some size, but it never rises above the rank of an accessory, so that the name zircon-syenite, which has been applied to these rocks is quite unjustified. Magnetite is not uncommon, sometimes in large grains, and pyrrhotite is seen in one specimen.

In thin section the feldspars, chiefly albite and orthoclase, show less tendency to microperthitic intergrowth than in the granites, though such are not rare. The orthoclase is frequently in Carlsbad twins, and the albite shows twinning lamellæ, but both are found in simple crystals. Microcline, spoken of by Rosenbusch as abundant, is rare in my sections. The nepheline calls for no special comment. While usually interstitial between the feldspars, small, stout prisms are often included in them. Sodalite is rare in the sections. In the rock from Mackerel Cove and from Great Haste Island it occurs decomposed to a dull, fine-grained aggregate (*Spreustein*) interstitial between the feldspars. This decomposition has taken place while the nepheline has remained perfectly fresh. Cancrinite, colorless in thin sections, was observed in the syenite from Salem Neck in small amount, but elsewhere was rare. It was identified by its cleavage and high birefringence.

Perhaps the most common of the ferromagnesian minerals is a deep brown, highly pleochroic biotite, which forms thick plates or stout prisms. An olive-green biotite also occurs on Salem Neck, but is much less common. Hornblende is not very abundant, except in the foyaites of Salem Neck. It is greenish-brown, or a deep olive-green, and highly pleochroic, and much resembles the aegirite. In a few cases it occurs as a border around

aegirite. The pyroxenes are represented by a very pale, greenish-gray aegirite-augite (**c** $\wedge c = 34°$) and by green aegirite. The former occurs in quantity only in one specimen from Salem Neck with biotite. The ægirite is abundant in many sections, often in those free from biotite. It is clear grass-green, with strong pleochroism: **a** = deep grass-green, **b** = grass-green, **c** = light greenish-yellow. The extinction **c** $\wedge c$ is about 7°.

Titanite, magnetite, and zircon are rare; apatite occurs in patches, but is not common. No eudialyte was seen. A few grains of a yellow, strongly pleochroic mineral, referred to laavenite, were found.

	I	II	III
SiO_2	58.77	59.31	60.39
TiO_2	0.31	0.32	....
ZrO_2	0.11	....	....
Al_2O_3	22.64	22.50	22.51
Fe_2O_3	1.54	1.93	0.42
FeO	1.04	1.40	2.26
MnO	trace	trace	0.08
MgO	0.19	0.17	0.13
CaO	0.74	0.46	0.32
BaO	none	....	....
Na_2O	9.62	7.98	8.44
K_2O	4.89	4.08	4.77
$H_2O(110°-)$	0.07	0.15	....
$H_2O(110°+)$	0.90	1.12	0.57
	100.82	99.42	99.95

I Nepheline-Syenite. Salem Neck. H. S. Washington anal.
II Nepheline-Syenite. Great Haste Island. H. S. Washington anal.
III Litchfieldite. Litchfield, Maine. L. G. Eakins anal. BAYLEY, Bull. Geol. Soc. Amer., Vol. III, p. 241, 1892, contains trace of CO_2.

The foyaites show their structure in the hand specimen very clearly, most surfaces exhibiting a multitude of long, glistening cleavage surfaces of feldspar, arranged in parallel position, forming a sort of flow structure. Surfaces in one direction, however, are made up of flat isometric feldspar plates, owing to the tabular development of the crystals parallel to *b* (010). They are clear ash-gray, and not very fine grained. In thin section they

differ from the preceding chiefly in the structure, which is eminently trachytic. The minerals are much the same, and the feldspars differ only in habit.

Two analyses of the nepheline-syenites were made, one of a specimen from Salem Neck west of the Fort, which was collected on the excursion of the A. A. A. S. in August 1898, under the guidance of Mr. Sears; the other of a specimen from Great Haste Island, given me by that gentleman. The former is foyaitic in microstructure, the latter more ditroitic. Both are apparently quite fresh. Analysis III, of litchfieldite, is introduced for comparison.

The two analyses resemble each other very closely, except that the former has more soda and less iron oxides. Compared with nepheline-syenites from other regions, the Salem rocks are notably poorer in lime and magnesia, and rather higher in silica than most. In these respects they correspond closely to the nepheline-syenites of Litchfield, Maine, and Red Hill, New Hampshire, described by Bayley,[1] especially the former. This is an extremely albite-rich type, to which he has given the name of Litchfieldite. Bayley regards the orthoclase as secondary for the most part, but it is to be observed that, even if it owes its present form to secondary processes, it must have existed in the original rock. Although the composition of the ferromagnesian minerals in the Salem rock is not known with certainty, yet a rough estimate may be made of its mineralogical composition. This is given in **Ia**, the composition of the Litchfield rock as calculated by Bayley from good data being given in **IIIa**. It will be seen that there is much similarity between the two.

	Ia	IIIa		Ia	IIIa
Albite	43	46.9	Lepidomelane	..	6.9
Orthoclase	27	27.0	Biotite, etc.	6	...
Nephelite	20	17.0	Zircon, Magnetite, etc.	3	...
Cancrinite	1	2.0			

Pulaskitic Syenite.—In connection with the nepheline-syenites, and constituting a facies of them, are found rocks which

[1] BAYLEY, Bull. Geol. Soc. Amer., Vol. III, p. 231, 1892.

are either extremely poor in, or quite wanting in, nepheline. These are true syenitic rocks and among my specimens two main varieties may be distinguished. They shade into the preceding group by imperceptible gradations.

The first is found at a quarry on the north shore of Salem Neck, west of the Fort, and is essentially a border facies near the contact with essexite, which crops out close by on the other side of a small hollow. This is typically foyaitic (trachytic) in structure and shows the tabular feldspars and their parallel arrangement. A variety of this, met with farther east near the water's edge, is brownish and porphyritic through the presence of abundant feldspar tables strewn irregularly in a feldspathic groundmass. These syenites resemble the foyaites in all essentials, except that nepheline is absent and the feldspars are nearly always microperthitic. The colored minerals are olive-green hornblende, brown biotite, and green aegirite, all in about the same amount. Magnetite grains and an occasional apatite needle are also found.

This rock corresponds closely, both in evident structure and mineral composition, to the hedrumite of Brögger[1] from the laurdalite region, and which he defines as: "nepheline-poor to nepheline-free syenitic rocks with trachytic structure exactly corresponding to that of the foyaites." Since, however, its analysis (I) shows that it is decidedly more acid than Brögger's analysis of hedrumite, it would better be classed with the pulaskites.

The other type of syenite forms coarse-grained masses and veins in the nepheline-syenite, and is best represented by a specimen from Salem Neck given me by Mr. Sears. This shows a coarse-grained mass of pearly, tabular, alkali-feldspar crystals, arranged in radiating groups, with a little aegirite, etc., in black grains and a minute amount of magnetite. Under the microscope the feldspar tables are seen to be microperthite, though kryptoperthite is also seen, as well as albite alone, showing fine and clear twinning lamellæ. There is possibly a slight admix-

[1] BRÖGGER, Zeit. Kryst, Vol. XVI, p. 40, 1890. It is more fully described later in Erupt. gest. d. Krist. geb., Vol. III, pp. 183 ff., 1897.

ture of the anorthite molecule. The only colored component seen in the sections is a grass-green aegirite, but other ferromagnesian minerals are probably present. The large crystals are well shaped, but have borders of detached aegirite grains which are embedded in the surrounding feldspar. These grains extinguish simultaneously with each other and with the large crystal, forming a sort of pegmatitic zone. The aegirite has been apparently cariously corroded by the magma and the hollows filled with feldspar substance. Nepheline occurs very sparingly in small interstitial spots.

An analysis of this type yielded the results below, in II :

	I	II	III	IV
SiO_2	63.71	63.09	64.54	63.71
TiO_2	trace	0.45	trace	0.86
ZrO_2	....	0.06	....	....
Al_2O_3	18.30	18.50	18.13	16.59
Fe_2O_3	2.08	2.90	2.63	2.92
FeO	2.52	1.36	0.97	0.66
MnO	trace	trace	....	0.20
MgO	0.09	0.16	0.67	0.90
CaO	1.18	1.00	0.62	3.11
BaO	....	....	0.42	....
Na_2O	6.39	7.25	6.60	8.26
K_2O	6.21	5.23	5.99	2.79
$H_2O(110°-)$	0.09	0.21	....	....
$H_2O(110°+)$	0.17	0.62	0.31	0.19
P_2O_5	....	....	trace	....
	100.74	100.83	100.88	100.19

I Pulaskite (hedrumitic). Salem Neck. H. S. WASHINGTON anal.
II Pulaskite. Salem Neck. H. S. WASHINGTON anal.
III Pulaskite. Farnisvand. BRÖGGER. Erupt. gest. Krist. geb. III, 198. 1898.
IV Umptekite. Bank of the Umpjaur. Kola Penin. Finland. ROSENBUSCH. Elemente d. Gesteinslehre. 1898, p. 112. No. 5.

It is decidedly more acid than the normal type, carrying less alumina, a little more lime, and about the same amount of alkalis. It is evidently a rather acid syenite, but its real affinities are uncertain. It bears a resemblance to the umptekite which Ramsay observed on the borders of the nepheline-syenite of Kola, and it is of interest to note that Rosenbusch speaks of

umptekites occurring at Curtis' Point, Beverly, and other localities of the Massachusetts region, and also refers the nepheline-syenite of Red Hill, N. H., to this type.[1] The umptekites, however, are typically soda-hornblende rocks, and markedly higher in lime and magnesia, as seen in analysis IV. They certainly show greater analogies with the pulaskites as defined by Brögger: "Nepheline-poor to nepheline-free rocks, also quartz-free or very poor in quartz, poor in dark minerals and with eugranitic structure, in which a development of the feldspars with rectangular or long rectangular sections predominates." It is of interest to observe also the affinity with the albite-rich litchfieldite. A rough calculation of the analysis II gives albite about 58.5 per cent., orthoclose about 31.5, anorthite about 2, and the rest (8 per cent.) colored minerals and magnetite. This rock, then, may be called a pulaskite, or rather a pulaskitic phase of the nepheline-syenite. It must be borne in mind, however, that both this and the hedrumite are only facies of the main foyaitic mass, and not independent rock bodies, at least so far as is yet known.

Orbicular syenite.—A small but interesting type of syenites is found near Bass Rock, Gloucester, and also, according to Mr. Sears, at Salem Neck, Beverly, and on the Manchester Shore, the development being in all cases quite local. Near Bass Rock, the only locality examined by me, it occurs as rounded inclosures in an outcrop of granite, apparently in place, together with similar masses of a dark, coarse-grained dioritic rock, which will be described later. A narrow compound dike of aplite cuts the granite and its inclosures. Of the occurrence of Mr. Sears' specimens I have no data at hand. The syenites are fine-grained and compact, with a groundmass of a light-gray color. Scattered through this are phenocrysts of black hornblende some 0.5 c.m. long, each hornblende being surrounded by a narrow zone of white, finely granular feldspar. These small areas of black with white borders give a peculiar orbicular appearance to the specimen.

[1] Cf. ROSENBUSCH, Elemente d. Gesteinslehre. 1898, pp. 113.

Under the microscope the groundmass is seen to be finely granitic in structure, and to be composed largely of alkali feldspar in xenomorphic grains, microperthite being rare, with only an occasional plagioclase grain. There are also present, somewhat abundantly, small, clear, rectangular sections of orthoclase. A little quartz occurs, especially as small interstitial grains. Irregular anhedra of colorless or very pale greenish-gray diopside are scattered through the groundmass. These are often surrounded by a zone of green or bluish-green pleochroic hornblende, which does not seem to be secondary. Magnetite grains, often surrounded by an amphibole halo, are not uncommon, and small apatite needles are met with.

The large black spots consist essentially of an olive-green, slightly pleochroic, hornblende. These hornblende areas are not continuous, but are made up of more or less rounded spots of hornblende, between which lies a granitic mesostasis of feldspar grains like the groundmass. The small hornblende spots in each area have their cleavage cracks parallel and extinguish simultaneously, so that the structure is micropoikilitic. The white borders are of granular feldspar, free from pyroxene, in which the small rectangular orthoclase sections seem to be more common. They pass insensibly into the surrounding groundmass.

A specimen given me by Mr. Sears from Salem Neck (?) is similar, but the structure of the groundmass is more trachytic, the pyroxene is largely replaced by dark green biotite, and the hornblende phenocrysts are much darker in color. The orbicular spots are quite ophitic in structure, owing to the tabular development of the feldspars. No analysis of these rocks has yet been made.

HENRY S. WASHINGTON.

(To be Continued)

THE GENETIC CLASSIFICATION OF GEOLOGICAL PHENOMENA.

In the consideration of every branch of natural knowledge, one of the first phases to receive attention is some ready means of comparing the various phenomena presented. Gradually there grows up some systemization of the facts and principles, that afterwards reflects the particular stage that the branch at that time attained. This orderly arrangement is the initial step in raising the branch to the dignity of a science.

Scientific advancement may be measured by the degree of taxonomic completeness shown, and by the character of the criteria regarded as critical. As progress is made a rapid evolution in the fundamental plan of grouping the facts takes place. In the beginning, a classification, crude though it may be, is outlined from those superficial features that, at first glance, are the most striking. This is, at a later stage, modified to one in which similarity of common characters, irrespective of natural relations, is taken into account. A vastly more advanced conception is classification based upon affinity, in which for similarity of features is substituted similarity of plan. The final stage is one in which origin, or causal relationship, is the governing principle. This is genetic classification.

At the present time the science of geology is just entering upon the stage last mentioned. As yet, no complete genetic scheme has been proposed. However, various attempts have been made to emphasize the principle of genetic association. All of these efforts appear to be too closely wrapped up in the older conceptions to show very much real advancement over them. They plainly indicate that the time is now ripe to seriously plan for a purely genetic arrangement of geological phenomena.

The older text-books on geology treat of all things geological

from the standpoint of the finished products. The idea that the latter are the visible expressions of many and constantly changing agencies has received only indirect or secondary practical consideration. As a result the production of many, if not most, geological features are loosely, or in a very vague way, ascribed to causes that are very complex. That is, instead of being single and simple the ascribed agencies are in reality a combination of several very distinct causes. For example, rock weathering is usually spoken of as if it were a single process in operation; whereas it involves the action of at least three distinct forces, one of which is strictly physical and the other two chemical, that are called into play separately or in conjunction.

So far as concerns the standpoint of treatment, the newer text-books on geological science are not much of an improvement over the older ones. The antiquated plans of making the products all important and of not distinguishing between processes still thoroughly permeate them. In some cases a little more space than formerly is devoted to "dynamical" geology, and a little less stress is placed upon the so-called historical section. Otherwise, there is relatively small difference between the geological manuals of today, and those of a quarter or a half century ago.

At this time it is not quite clear just what are the real reasons for this lagging of the manuals so far behind the science itself. Not the least important factor probably is that, as a rule, the makers of popular text-books are not in a broad way creative or productive investigators. The advance movement in geology began nearly a score of years ago, and today it is quite generally appreciated by all active workers, who face the subject in nature.

While it was only natural that geology should finally come to be placed upon a strictly genetic, or philosophic, basis, it was due primarily to the modern geographic school that the first strong impulses in this direction were given. The geographers, however, have not developed their side of the subject in as purely a genetic manner as they would have us believe, or as their opportunities permit. They certainly began in the right way, but in

the multitude of new conceptions and the maze of geographic forms that were presented, the analysis of the simple processes that were continually at work was largely overlooked.

So far as I am able to see, Gilbert appears to be the only one who has yet struck the right chord in the attempt to classify, by the processes, geological phenomena. As long ago as 1884 this writer proposed a "Plan for a Subject Bibliography of North American Geology," in which the geological agencies, instead of products are given primary consideration. How far the scheme would have been developed had it been allowed to go on cannot now be inferred. Since that time nothing further has been done in regard to this matter. The arrangement, presenting partly the common subdivisions of the subject of geology as given in our text-books, indicates that the author did not have in mind a classification that can be regarded as strictly genetic.

A few years later McGee suggested "a purely genetic taxonomy of geology, designed to include geography." This plan is particularly instructive as illustrating another phase of the subject. A critical examination of the scheme clearly shows that it is not really genetic except in name. Each product is made to have a constructive and a destructive phase. This plan has been, it may be here mentioned, seized with avidity by the more progresssive geographers. Its method is particularly attractive when applied to topographic forms, especially since it has been fully recognized that they all have "life histories." It is manifest, however, from the whole treatment of the theme that this plan has for its actual foundation the product and not the process. Stages of construction and of destruction must necessarily center around the feature and not the agency producing it. The essential characteristic of this scheme is the twofold nature of the production of every geographic form. When it is remembered that in the old geology the product is the all important factor, and in the new the process, it is at once seen that the dual plan is based entirely upon the old conception, and that the truly genetic principle is lost.

The plans of classification by genesis that have been formu-

lated by the geographers have to be made much more comprehensive than they now are, before they can accomplish their intended service. To begin with, an adequate scheme should be based directly upon geological agencies. Topographic features are largely only the outward expressions of the internal arrangement of the earth. The two groups of characters should be paralleled. One represents form — the physiognomy; the other structure — or anatomy. Yet some geographic features have no measurable equivalent in structure; and many structures do not give rise directly to distinctive forms of surface relief.

In a strictly genetic arrangement, where the processes and not the products are made the central theme, the continual operation of two antagonistic forces does not really exist. Constructive and destructive agencies can be recognized only when the phenomena are made the basis of the scheme. Processes are merely operative. If coupled with the products at all, in classification, all must be regarded as formative or constructive. The product's destruction, its loss of identity, is wholly immaterial. The action of agencies is merely to produce constant change.

A truly genetic scheme for the classification of natural phe nomena thus always has prominently presented its underlying principle of cause and effect. All products must find accurate expression in terms of the agencies. Only then are the broader distinctions in geological classification rendered possible. The various taxonomic groups are made separable only when it is recognizable how, or in what manner, the component parts of the materials dealt with are influenced. Under one set of agencies and conditions a rock-mass is affected in one way, and the component units act altogether differently from what they do under another set of agencies. The primary groupings of the geological processes must be based, therefore, upon the manner in which these agencies affect the rock materials.

When rocks, or the materials with which geology has to deal, and through the medium of which geological phenomena take definite form, are carefully considered with reference to

their behavior under different physical conditions, it is found that, broadly speaking, they are acted upon in four very distinct ways: (1) In a most comprehensive manner all the rocks of the globe act as a unit, and are affected as such by only the cosmical forces. They are then considered in their astral relations. (2) Again, physical forces may affect rocks as great bodies, masses or formations. This may be regarded as their corporeal aspect. (3) Rocks may also be influenced only as particles. They are then treated of in their molar relations. (4) Finally, rocks are changed by the motions of their molecules and atoms. The molecular agencies, as understood in this connection, are those commonly termed physical (in its most limited sense) and chemical. Since, for geological purposes, it is hardly necessary to make any distinction between the two processes of this class, both are called molecular.

Each of the main groups, or kinds of geological processes, has its several minor categories, and each of these its particular phases. Activity of the subordinate agencies as comprehended under the latter give rise to the various classes of geological structure and geographic form.

While a complete arrangement of all geological phenomena, according to the plan suggested, would necessarily require a critical inquiry into the whole subject of geology, some of the principal features of such a genetic scheme may be indicated by the accompanying outline.

From this arrangement may be readily inferred many of the shortcomings of our existing systems. Two points are also prominently brought out. One is the frequent origin of very similar products through the action of diverse processes. The other is the complicated nature of most of the agencies that we commonly regard as simple. The absolute necessity is thus shown for a new series of brief, self-explanatory terms that will enable us to express with exactness the various processes according to the modern view or modified conceptions.

In enumerating some of the chief processes affecting the rocks a number of familiar terms do not appear. Among these

CLASSIFICATION OF GEOLOGICAL PHENOMENA BY GENESIS.

Processes (Geodynamy)			Structures (Geotectonics)	Forms (Geography)
Kind	*Category*	*Phase*		
Astral (*as a unit*)	Refrigeration		Rock	Envelopes
	Revolution	Climatic		
	Rotation	Eolic Hydric Lithic		Trade winds Ocean currents Geosphere
	Gravitation	Depressive Repulsive	Epeiroclines	Continents, oceans Tides
Copo-real (*as masses*)	Diastrophism (Solid)	Plicative Fractural Displacive Fissile Fluent Comminutive	Flexures Joints Faults, thrusts Cleavage, fissility Schistosity Brecciation	Mountain ranges, great lakes, and seas Salients Fault scarps
	Vulcanism (Liquid)	Intrusive Effusive Explosive	Dikes, veins, silts, necks, laccolites, basics, etc. Lave sheets Ash beds	Ridges (some), peaks, domes, etc. Mesas, lava fields Cones, craters
Molar [Physical] (*as particles*)	Seismism			
	Cementation	Compressive		
	Disintegration	Frigidic Caloric Biotic		Regolith, talus slopes
	Gradation	Eolic Glacic Hydric	Stratification	Dunes, sand ridges, etc. Moraines, drumlins, kames, drift-plains, basins, some lakes Coastal plains, peneplains, flood plains, deltas, valleys, drainage systems, etc.
	Automotion	Vital Anthropic		Coral reefs, shell-banks, etc. Mounds, etc.
Molecular, or chemical. (*As molecules and atoms*)	Decomposition		Fissures (some)	Sinks, caverns, etc.
	Induration			Crags, reefs, water falls (some)
	Metamorphism	Paramorphic Metasomatic		
	Mineralization		Mineral veins (some)	
	Precipitation			

may be mentioned, for examples, weathering, erosion, deformation, transportation, and deposition. These are names that, as technical terms, do not now mean very much. While they are commonly used, and perform useful functions in certain cases, they really indicate an imperfect state of knowledge of the subject, or rather remissness in careful discrimination. All are compound processes, and, involve the simultaneous action of several distinct agencies. Weathering includes, among other changes, the mechanical breaking down of rock-masses through the effects of heat and cold, the action of life or the application of pressure (disintegration); it involves the chemical alteration of some of the essential constituents, by which the identity of the rock-mass is lost (decomposition); and it also embraces, in its earlier stages, chemical change in which traces of the identity of the original rock are retained, but in which there has been some metasomatic replacement.

In the same way most of the other terms applied to "processes" are found to be ill-defined. Even metamorphism, which is, in the present connection, used in its limited petrographic sense, is a loose title. Usually it carries with it the idea of rock induration. Its complexity is hinted at by the use of such compounds as "contact" metamorphism and "regional" metamorphism. It actually embraces both metasomatic and paramorphic alteration, and sometimes also mineralization and cementation. Certain diastatic and vulcanic influences also profoundly affect its exact expression.

To one trained in some other than geological science, the most striking feature of the latter is a certain vagueness that seems to pervade the entire field. This is also the main difficulty that every beginner has to overcome. While after a time this trouble ceases to impress itself on the geologist himself it is nevertheless glaringly apparent in his conversation and especially in his writings. The outcome of closer attention to the only natural scheme of classification, the genetic one, is clearer discrimination of facts, greater precision of statement, and vastly better comprehension of the whole subject.

CHARLES R. KEYES.

STUDIES FOR STUDENTS.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

IV. AVES.

THAT the birds were derived from the reptiles there is little doubt, the structure of the limbs, head, the thoracic and pelvic girdles and the feet all show a close resemblance to that of the same regions in the reptiles. Especially is this true in the more primitive birds. The general characters that are used to distinguish the class *Aves* are the development of the anterior limbs as flying organs and the accompanying atrophy of the digits of the front foot; the fusion of the bones of the skull to form a solid brain case; the fusion of the bones of the pelvis to form a solid mass of bone; the fusion of more or fewer of the dorsal vertebræ and the development of feathers. To these characters there might be added for all recent birds the absence of teeth. In the most primitive bird that we know there is not one of these characters developed in anything like a complete state, except the presence of feathers. In fact, if it were not for the fortunate accident of the preservation of the fossil in the fine grained beds of the Lithographic slates of Solenhofen, so that a cast of the feathers has been preserved, there would be some difficulty in deciding the true nature of the animal. The bones of the head and the pelvis are not coössified; the digits of the anterior limb are developed with functional claws; the vertebræ are distinct and there are many teeth in each jaw.

The Dinosaurs have been regarded as the direct ancestors of the birds, both *Compsognathus* and *Ornithomimus* of the Theropodous division having been considered as the forms from which they were derived, however there is not sufficient proof to

warrant our acceptance of either of these forms. Haeckel in his work on the phylogeny of the vertebrates thinks that the ancestor of the birds must be sought among the most primitive of the Dinosaurs of the Triassic or even earlier, among the *Rhyncocephalia* and the *Proganosauria*. Smith Woodward in his very recent work on Vertebrate Palæontology is content to say, "The earliest known birds exhibit a distinct approach to the *Reptilia* in several characters, but do not afford any indication as to the particular group from which they evolved. The general opinion is, that they are more closely related to certain *Dinosauria* than to any other forms hitherto discovered."

Following the classification adopted by Smith Woodward and in Parker and Haswell's Zoölogy, the class *Aves* may be divided into two subclasses, *Archæornithes* and *Neornithes;* the same groups were called by Haeckel, *Saururae* and *Ornithurae*. The first subclass is characterized by the features mentioned above. There is but one genus known and this is represented by but three specimens, two nearly perfect skeletons and a single impression of a feather.

Archæopteryx from the Lithographic Beds of the Upper Jurassic of Bavaria. Besides the characters mentioned above the animal was distinguished by the possession of a very long bony tail with a pair of feathers growing from each vertebra. The body of the animal was well covered with feathers and the remiges of the wings were well developed. It was about the size of the ordinary crow.

The *Neornithes* are divided into two groups, the *Ratitæ* and the *Carinatæ;* the flightless and the flying birds. The first group is of rather variable limits, some authors including in it all the birds without wings or with poorly developed wings without a keel upon the sternum, and without considering the origin of the condition, whether it is original, persistent from very early forms, or whether it is the result of degeneration from lack of use. Thus Smith Woodward includes among the *Ratitæ* certain forms that are considered by other authors degenerate *Carinatæ*.

The divisions *Ratitæ* and *Carinatæ* are assigned different values by the various writers on the subject, some considering them as orders and the other groups of the birds suborders, while others regard them as divisions of their class and all the other groups as orders. Probably the latter has the greatest following among zoölogists. It will be possible here to consider only those groups that are of importance in geological history.

Æpyornithes: extinct, gigantic birds represented by fossils from the post-Pleistocene of the island of Madagascar. They resembled the living *Apteryx* of New Zealand. *Æpyornis* is the most typical genus. It was of great size, the long bone of the leg, tibio-tarsus, was about two feet and a half long. In general form the members of this and the succeeding order resembled the modern ostriches.

Immanes.—The "Moas" or *Dinornithidæ*, were gigantic forms that existed as late as historical time, they were hunted by the natives of the island of New Zealand, where they were developed. They are not known from formations earlier than the Pleistocene, with the possible exception of a few fragments from what may be the Pliocene. They closely resemble the living *Apteryx*, and are sometimes grouped with it and the Emus and Cassowaries in an order *Megistanes*.

Dinornis is the best known of the genera; the scapular arch was almost entirely atrophied and the sternum was entirely without a keel; the hind legs were very stout and strong; the largest known species stood a little over ten feet high.

Pachyornis was remarkable for the massive nature of the hind limbs; as a whole the animal was smaller than the *Dinornis*.

Most of the existing Ratite birds are known from the superficial deposits of the countries where they are now found; an extinct Emu is known from the eastern part of Australia; remains of Rheas are found in South America and the Ostriches are represented by remains from the Siwalik Hills of India and from the Island of Samos in the Mediterranean.

Carinatæ.—Next to the *Archæopteryx*, probably the most interesting group of birds that is known are the peculiar toothed

forms from the Niobrara Cretaceous of Kansas. These were described by Marsh and called by him the *Odontornithes*, he distinguished two orders, the *Odontolcæ* and the *Odontormæ* (*Icthyornithes*).

Odontolcæ: large, flightless, swimming and diving birds that resemble the modern diving birds, Loons, etc., in many respects, and the Ratite birds in others. The front limbs are almost entirely atrophied, the humerus being represented by a slender stylet of bone; the skull was elongate and the jaws were furnished with many sharp teeth that were set in a common groove for each jaw.

Hesperornis, the most typical genus, was a large form about three feet high. A similar form *Enalornis* is indicated by remains from the Greensand of Cambridge, in England, but the structure of the anterior limbs is as yet unknown.

Odontormæ (*Icthyornithes*): much smaller birds than the former with well developed wings; the jaws were long, as in the preceding genus and were provided with teeth that were set in individual sockets; the vertebræ were peculiar in that the faces, both anterior and posterior, were deeply concave. The bird was much like the modern Tern in external characters.

Icthyornis is the only well-known genus from the Niobrara Cretaceous of Kansas.

The modern birds have many representatives among the fossil forms of the late Tertiary, among the most interesting of these are:

Gastornis, a large flightless bird from the lower Eocene of the western part of Europe. It was peculiar in that the bones of the skull remained separate instead of forming the usual solid brain case.

Apatornis, *Diaphaptoryx*, and *Aphanapteryx* from New Zealand, the Chatham Islands, and Mauritius respectively were gigantic rails that greatly resembled certain of the living rails.

Phororachos was an enormous raptorial bird whose remains are found in the Tertiary of Patagonia.

The Dodo (*Didus*) and the Solitaire from the islands of

Mauritius and Rodriguez were large ground pigeons that had lost, to a great extent, the use of the wings; they were found living by the first travelers that visited the islands, but were speedily exterminated.

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V. MAMMALIA.

The earliest known remains of the mammals are from the Triassic rocks of England and America. Between these earliest of the mammals and their direct reptilian ancestors there is but a very little gap, even in the imperfect record afforded by palæontology. Every step in the transition from the reptilian structure to the mammalian can be traced in the fossil forms, except the final disappearance of a separate bone in the skull, the quadrate, which supports the lower jaw, and the coalescence of the many bones of the lower jaw to form the single mandibular bone of the mammals.

Recalling the structure of the Theriodont and the Gomphodont reptiles of the Permian time we have no need to be surprised at the early appearance of the mammals in time. Speaking of the origin of the mammals, Osborne has said: "Two of the types of the Theromorphs of the Permian and Lower Triassic, namely, the *Theriodontia* and *Gomphodontia*, supply many of the characters which we have expected to find in the ancestry of the Mammals. In fact, they embrace the few osteological characters placed in Haeckel's Promammalia, or Huxley's Hypotheria, as well as the more numerous characters which we have

subsequently put into the mammal archetype. The *Theriodontia* resemble in their dentition and structure the minute *Protodonta* described by Osborne from the Triassic, but differ in the compound character of the jaw bones, as well as in their surpassing size. In tooth structure they are also prototypes of the *Triconodonta* or Marsupials of the Jurassic period. On the other hand, the herbivorous *Gomphodontia*, including *Tritylodon*, are prototypes of the great phylum of Multituberculata, which, in turn, upon extremely slender evidence, however, have been associated with the Monotremata."

So close is the resemblance between the reptiles and the mammals at this point that one of the *Gomphodontia*, the Tritylodon mentioned by Osborne, was originally described from the skull as a mammal by Owen. The Mammalia are generally divided into three subclasses, the *Prototheria*, *Metatheria*, and *Eutheria*.

PROTOTHERIA a small group comprising among the living forms only the peculiar Monotremes, the Duckbill (*Ornithorhynchus*), and the Spiny Anteater (*Echidna*) of Australia. The animals are characterized by the possession of a distinctly reptilian type of shoulder girdle, with distinct interclavicle and coracoid bones; by the presence of a single external opening for the excretory and genital organs and by their oviparous method of reproduction. The Duckbill has an edentulous horny covering to the jaws in the adult stage that has given it its name, but in the very young there are two or more broad flat teeth in each jaw that recall very strongly the teeth of the *Gomphodontia*. There are no fossil remains of these forms known earlier than the Pleistocene. The bones of a large species of the Echidna have been found in deposits of that age in Australia.

The number of forms of the fossil mammals is so great that it will be impossible to discuss many individual genera, as was done with the preceding groups, and in all except especially important cases the descriptions must be limited to the families or even larger divisions.

METATHERIA, animals usually called *Marsupalia;* possessed of

a pouch in which the young are borne by the mother for some time after birth; there are a pair of bones in the abdominal wall that are attached to the anterior end of the pubis on each side and support the pouch; the shoulder girdle is of the usual mammalian type.

Multituberculata, or *Allotheria*, as they are sometimes called, is a group of rather doubtful relations; they have been regarded as belonging to both the *Prototheria* and *Metatheria*, but probably belong with the latter; they are known only from fragments of the skulls and from isolated teeth. The time range of the forms is rather limited, extending from the Upper Jurassic to the Upper Cretaceous. There are three families known: the *Bolodontidæ*, *Plagiaulacidæ*, and the *Polymastodontidæ*.[1]

Bolodontidæ: forms in which the premolars are somewhat molariform and the upper ones have four tubercles. The molars of the upper series have two rows of tubercles. There were strong incisor teeth. *Bolodon*, from the Purbeck layers of Dorsetshire; *Allodon*, from the Upper Jurassic of Wyoming; *Chirox*, from the lowest Eocene, Puerco, of New Mexico.

Plagiaulacidæ: known mostly from the teeth of the lower jaw. The incisors large and rodent-like, the premolars different from the molars, compressed laterally, the posterior one much larger than the rest, and having the side corrugated by deep grooves that extend diagonally in an antero-posterior direction, making the tooth a most efficient grinding organ. The molars low and flat, the lower with two and the upper with, probably, three

[1] The student must recognize that after the mammalian type of life was developed there were no changes in that group of a magnitude comparable with those which produced the various groups of the reptiles. Until comparatively recently the changes considered have been those which centered in the development of the teeth and the limbs, and it was by the study of these changes that the morphology and the classification of the various groups has been worked out. It will thus be necessary to speak in some detail of these regions. For information on this subject the student is referred to the chapter on Kinetogenesis, chap. vi, in PROFESSOR COPE'S last book, Primary Factors of Organic Evolution, published by the Open Court Publishing Company of Chicago, 1896. The book has an especially valuable bibliography of the same subject. PROFESSOR OSBORNE has published in the American Naturalist for December 1897, an illustrated article bearing on the same subject entitled "Tritubercly: A review dedicated to the late Professor Cope.

series of tubercles. *Microlestes*, Upper Trias, Rhaetic, of Wurtemberg and England; *Plagiaulax*, Purbeck of England; *Ctenacodon*, Upper Jura of Wyoming; *Ptilodus*, Puerco Eocene, of New Mexico, under this last name Osborne includes as synonyms most of the names given by Marsh to the forms described by the latter author from the Laramie Cretaceous; *Meniscoessus*, from the Laramie Cretaceous of Wyoming, under this name are grouped as synonyms many of the remaining described forms from the same region. *Neoplagiaulax*, from the lowest Eocene of France; *Abderities*, as well as many imperfectly known forms, from the Eocene, Santa Cruz formation, of Patagonia.

Polymastodontidæ: lower jaw with a very large and strong incisor tooth greatly resembling that of the recent rodents, two large molars with two rows of tubercles and a very small premolar. This form is quite near the rest of the group, but is easily distinguished by the absence of the enlarged premolars and the much larger size of the animal.

Polymastodon, from the Puerco Eocene of New Mexico.

The study of these forms has led to the best knowledge we have of the changing conditions at the end of the Mesozoic time; thus from a comparison of the similar types in the preceding and the succeeding ages we are led to the conclusion that as far as the faunal relations go the Eocene is very much nearer to the Upper Cretaceous than is the Jurassic, and this means, possibly, a slighter change in the conditions, climatic and otherwise. Osborne says: "The Laramie mammals are surprisingly near to those of the Puerco, and in some cases almost identical with them; in other cases they are of a somewhat older type, ... the greatest gap to be filled by future discovery is between this Laramie fauna and the Jurassic. For this Laramie fauna is separated from the Puerco about as widely as the Puerco is from the Wasatch, but no more widely; whereas it is separated by a profound gap from the Jurassic fauna."

The *Marsupalia*, *Metatheria* proper, is divided into two groups, the *Polyprotodonta* and the *Diprotodonta*, according to the presence of two or more than two incisor teeth in the jaws.

Polyprotodonta: carnivorous or insectivorous forms of small size with a large number, 4–5, of incisor teeth and many molar and premolar teeth, 8–12 in opposition to 6–7 possessed by recent forms. The premolars are simpler than the molars.

The suborder is divided by Osborne into three groups, *Protodonta*, *Triconodonta*, and *Trituberculata*. The first, the *Protodonta*, is distinguished by having the premolars simple and conical in shape and the molars with a middle part slightly elevated above a posterior and an anterior accessory cone. The molar teeth are single-rooted, but there is a deep groove on each side that indicates the coming division of the root into two parts. The group is represented by two specimens only. These are from the Triassic rocks of North Carolina and consist of the lower jaws only. *Dromotherium* and *Microconodon*.

Triconodonta: forms very similar to the last, but with a smaller number of molar teeth. The middle cone of the molars is better developed and the accessory cones are separated farther from the main one and have a much greater part in the function of mastication. The roots of the teeth are entirely separated. The forms are almost entirely from the Jurassic layers of England, and Wyoming. Typical genera are:

Amphilestes, Oolite from near Oxford, England.

Phascalotherium, Oolite from near Oxford, England.

Tinodon, Upper Jurassic of Wyoming.

Priacodon, Upper Jurassic of Wyoming.

Dicrocynodon, Upper Jurassic of Wyoming.

Trituberculata: small forms with many molar teeth, the crowns of which are supplied with three tubercles arranged in the form of a triangle with apex of the triangle pointing inwards in the upper teeth and outwards in the lower; the importance of these forms is best realized when we remember that this tritubercular arrangement of the tubercles of the teeth is the primitive type from which all the remaining types of mammalian dentition have been derived. The *Amphitheridæ* and the *Amblotheridæ* are the two most primitive families of the suborder.

Amphitherium, from the Oolite of England, near Oxford.

Amblotherium, from the Purbeck of England.

Dryolestes, from the Upper Jurassic of Wyoming.

The *Myrmecobidæ*, *Peramelidæ*, *Dasyuridæ*, and *Didelphyidæ* are all families containing living forms, the last two have members from rocks as old as the earliest Eocene. It is of interest to note that while the family *Didelphyidæ*, the opossum, is at present confined to the North and South American continents it formerly ranged over the whole of Europe and England.

Diprotodonta.— This suborder is distinguished by the presence of only two incisor teeth in the upper jaw and one in the lower. The premolars are like the molars, or may be developed as long cutting organs, as in the *Allotheria*. There are several families, but only two are of interest to us here, as they are the only ones that contain fossil forms. The suborder, living forms as well as extinct, is entirely confined to the Australian region.

Thylacoleo is the single representative of the *Thylacoleonidae ;* it was a large form about the size of the lion, with strong incisors and one of the premolars in each jaw greatly elongated in the antero-posterior direction, and compressed from side to side so as to form a long cutting edge; the rest of the dentition is quite weak. The posterior part of the head is very wide, but it narrowed rapidly as it approaches the anterior end.

Diprotodon and *Nototherium* are the representatives of the *Diprotodontidae*. The skull of the first was nearly three feet long, the incisor teeth were developed as gnawing teeth, with enamel on the outer side only and set in deep alveoli. The posterior teeth lacked the cutting edges of *Thylacoleo*, and were adapted to grinding up vegetable material. The whole form had the bulk of the rhinoceros; the structure of the feet is unknown. *Nototherium* was very similar to this form, but was considerably smaller.

Eutheria: Animals in which there is no marsupium; the embryo is nourished by the development of a placenta that attaches it to the mother. This includes all the remaining forms of the mammals. Palæontologists recognize ten orders of the

Eutheria: the *Cetacea, Sirenia, Ungulata, Tillodontia* (*?*) *Rodentia, Carnivora, Insectivora, Chiroptera, Edentata and Primates.*

Edentata.—These are the lowest of the Eutheria in the scale of development. The group is characterized by the imperfect development of the dentition; the teeth are few in number, and the enamel is lacking from the surface in the more recent forms. That they are degenerate forms is shown by the fact that the earlier order had perfectly formed teeth; many of the steps in process of degeneration have been traced. Three suborders are recognized: *Nomarthra, Xenarthra,* and *Ganodonta.* The first of these is of little importance from a palæontological standpoint; it is composed of forms confined to the tropical parts of Asia and Africa. It is separated from the *Xenarthra* by characters of the vertebræ.

The *Xenarthra* is divided into five suborders, the *Tardigrada, Dasypoda, Gravigrada, Glyptodontia,* and *Ganodonta.* The first two are confined to the recent and the later Tertiary of South and Central America.

Gravigrada.—These forms, now extinct, were of gigantic size; the body was large and clumsy with a powerful tail that, perhaps, aided the animal in assuming the upright position; in the later forms, perhaps more than in the earlier, the animals walked with the side of the foot presented to the ground; the teeth were few and confined to the posterior part of the jaws; they were without any enamel upon the surface. The animals were in fact large ground sloths; they probably obtained their nourishment by uprooting trees and shrubs and feeding upon the leaves and smaller branches.

Megatherium was the largest of the forms, reaching a length of 18 to 20 feet, and a height of about 8 feet. The teeth placed close together at the posterior part of the jaw, exhibit cross ridges from the presence of slightly harder dentine. The animal is known from all parts of South America, and as far north as Georgia, South Carolina, and Texas.

Megalonyx.—This form is the representative of a separate family from the preceding; the most anterior of the molar teeth

stands far in front of the remainder, and has the appearance of a canine. The genus appears to be confined to the latest deposits of the Tertiary in the United States, and is found in the cave deposits of the southern states. The animal reached the size of an ox.

Mylodon, another form is distinguished from the others by the appearance of slight irregularity in the form of the teeth; instead of straight peg-like form, they are triangular, and the teeth of the lower jaws are somewhat figure eight shaped in outline. This genus was fully as large as the *Megatherium* and had even a greater geographical range, species being known from the pampas of the Argentine Republic, and from the caves of Oregon.

A very large number of forms have been described from the deposits of Patagonia and the Argentine Republic, and a smaller number from other parts of the southern continent, many being found on the west coast, to reach which place they must have either crossed the Andes, or emigrated down the west coast from far up in the United States. The geological range seems to have been from the upper Eocene or the Oligocene to the latest Pliocene.

Glyptodonta.—These were animals in which the body was covered by a strong carapace of bone that was made up of many small ossicles of different shapes, joining each other by suture. The armor was confined entirely to the dorsal surface, there being no plastron or ventral plate as in the turtles. The tail was large and covered with the same armor as the back. The skull was very short and high with a lower jaw of great vertical thickness. The teeth were elongated in the anterior-posterior direction, and the sides of the teeth were marked by deep vertical grooves that nearly divided the teeth into three parts. The vertebræ of the dorsal region were all united into a long tube, and the lumbar vertebræ were anchylosed with the sacrum, thus practically destroying any mobility of the spine. The feet were provided with broad, almost hoof-like claws. The animals sometimes reached a very large size. The whole suborder is extinct.

Glyptodon: a very large form that ranged from the southern part of South America as far north as Texas and Florida. The animal was about six feet long, and reached a height of three feet at the most elevated portion of the carapace. The dermal plates are sculptured in the form of a rosette. The tail is covered with a series of bony rings that are attached to the processes of the vertebræ within.

Panocthus: a large form that is confined to southern part of South America; very similar to the *Glyptodon*. The carapace was made up of four and five-sided pieces with a tuberculated surface instead of the rosette arrangement. The anterior part of the tail was protected by 6–7 large bony rings, but the posterior part was enclosed in a solid tube of bone that was slightly flattened; the surface of this tube was covered with small plates that in places gave room to larger ones that seem to have been the bases of some sort of protuberance, horny or bony. The form reached about the size of a rhinoceros.

A large number of these forms have been described from the late Tertiary deposits of Patagonia, and the Argentine Republic. The majority of them come from the Miocene and the Pliocene, though a considerable number are from the earliest, the Santa Cruz Tertiary.

Ganodonta.[1]—This group was founded in 1896 by Wortman, and considered by him as a suborder of the Edentata. The group is made up of a part of the order *Tillodontia*, which was originally considered as the ancestral form of the rodents. Not until the teeth of one of these forms was found in connection with the fore limb was it determined that they were Edentate in character. The fore limbs are similar in every respect to those of the *Tardigrada*, but the teeth are different in that they are not devoid of the enamel covering and in the presence of the anterior teeth, the incisors, and the canines. These forms occur in the earliest Eocene Puerco beds of New Mexico, and are undoubtedly the earliest forms of the Edentates. They are of

[1]Science, December 11, 1896, p. 865., Bull. Am. Mus. Nat. Hist., Vol. IX, p. 59. (Contains a full description of the Ganodonta and its geological relationship.)

extreme interest as indicating the origin of the group which has been for long one of the greatest problems of the palæontologist. Other than the interest attaching to the origin of the group is that of the geological possibility of the forms getting into the southern continent in the early Tertiary time. These forms undoubtedly originated in the United States. As there is no trace of them in the basal Eocene of South America. and they appear in great numbers and highly developed in the Middle Eocene, it seems certain that they must have emigrated from the northern land. There is little possibility that they could have taken the northern route and gained the land of Asia by the northern connection, and then worked into South America by the Antarctic continent; this is further borne out by the fact that there are no known remains of the group from the Old World beyond the incompletely identified specimen of one genus. It seems probable that there must have been a temporary connection between the two continents in the earliest or the Middle Eocene. That the forms found the conditions of life exceptionally favorable in the southern continent is evidenced by the extraordinary development both of species and of individuals.

Cetacea.—This order bears very much the same relation to the land mammals that the Plesiosaurs and the Icthyosaurs bore to the early land reptiles. The limbs have degenerated and become adapted as swimming organs, the bones of the proximal portions becoming shorter and losing their distinctive character, while the phalanges become much more numerous and there may even be added digits. In most of these forms also the hind limb is lost; the teeth become simpler and disappear in some forms; the whole body takes on the fish-like form that seems to be requisite for the aquatic life; the hair disappears and is represented by only a few scattering bristles. These remarks are equally applicable to the succeeding group, the *Sirenia*.

The *Cetacea* are generally divided into three groups, the *Archæoceti*, the *Odontoceti*, and the *Mysticoceti*. The last two groups, the recent dolphins and the whales are represented in the fossil state by specimens from the Eocene, showing all the

characters of the recent forms. The first group, the *Archaeoceti*, is represented by a form that is known from all parts of the world, *Zeuglodon;* it has an elongate skull like the alligator, but still possesses the dentition of the land animals, in that it is differentiated into premolars and molars; the position of the nostrils and the extent of the nasal bones are also typical of the land forms, but the limbs are those of a water animal. As the form is the earliest known, it is regarded as the nearest to the primitive ancestor of the *Cetacea*. The carnivorous dentition has led to the conclusion that it, and consequently all of the order was derived from a carnivorous mammal. The high degree of development of the order at its earliest appearance, indicates that these animals must have begun their specialization some time in the Cretaceous before we know of any mammals that could have produced them.

The *Sirenia* have a like history to the foregoing group. They are, without doubt, the descendants of land-living forms, but are derived from ungulates, probably from the primitive *Condylarthra*, instead of from carnivorous forms. The earliest remains are from the Eocene rocks, and show that the animal was at that time still in possession of a pair of rudimentary hind limbs. Specimens are known from most of the countries of the earth, and from all deposits from the earliest Eocene up. *Rhytinia*, Steller's Sea-cow, became extinct as late as the middle of the eighteenth century. It was found in great abundance on the shores of Alaska and the neighboring islands by the early explorers, and was slaughtered for food by the whalers.

Ungulata.—This is one of the largest groups of the mammals, including all of the herbivorous forms with the exception of the rodents. They are all land-living forms, with the limbs modified as organs of locomotion and the terminal phalanges armed with broad, flat, horny coverings or hoofs. The dentition is adapted to a vegetable diet or to an omnivorous one, as in the pig. The dentition is diphydont, *i. e.*, there is a milk set that is later replaced by a permanent one.

There are generally recognized eight suborders of this order:

Condylarthra.
Perissodactyla.
Artiodactyla.
Amblypoda.
Proboscidea.
Toxodontia.
Typotheria.
Hyracoidea.

The *Condylarthra* are forms with five functional digits on each foot; plantigrade in the habit of walking, and with small hoofs on each digit. The astragulus has a long neck, and the distal articular face, for the navicular, is rounded. The teeth are multitubercular and complete in number in each jaw. It was in these regions that the changes took place that have made it possible to trace out the lines of development of the ungulates, and, as Cope thought, the lines of the *Carnivora* and the *Primates* as well.

There are several families of the suborder, but it will be as well, probably, to take one of the forms from one of the families and describe it as typical of the whole group.

Phenacodus is the best known of the suborder. By great good fortune the nearly perfect skeletons of two individuals are known. The whole animal was about the size of a mastiff dog. The first and fifth toes on both the fore and the hind feet are shorter than the others, and show already the tendency to a reduction in number that is the dominant line of evolution in the foot structure of the ungulates. Another thing, the bones of the two rows of the carpus and the tarsus are arranged one above the other, instead of being alternate in position, *i. e.*, one of the upper row being opposite the space between two of the lower row. The latter arrangement is readily seen to be by far the strongest, and the development of the ungulates is marked by the gradual acquisition of this alternate arrangement of the bones in place of the serial arrangement of the *Condylarthra.* There was a long tail; the skull was low and flat, with large

orbits that are open behind; the multitubercular teeth indicate that the animal was omnivorous in its diet; the brain was small and smooth, devoid of deep convolutions such as exist in most of the mammalian brains.

Periptychus was a very similar form from the same horizon as Phenacodus.

Pleuraspidotherium and *Orthaspidotherium* are forms from the lowest Eocene, Cernays, of France; they are similar in the essential features to the American *Condylarthra*, and show that the group was widespread in its geographical range, as might be expected from its generalized characters.

Starting from the *Condylarthra*, with its generalized dentition and five-toed feet, there were developed two lines of the *Ungulata*, which include all of the living and extinct forms. In one line the weight of the body is borne on the three middle digits of the feet, or, in the more advanced forms, on the middle one of all the digits. These forms were called by Owen, in 1849, the *Perissodactyla*. They are generally referred to as the "odd-toed" animals, with the idea that there is always an uneven number of toes on the feet, but this is erroneous, as some members of the group have four toes on the feet; the essential thing is that only three of them take any part in supporting the body, the other being a rudiment from the original pentadactyl arrangement. The next group of the *Ungulata* is the *Artiodactyla*, the forms with an even number of toes supporting the body. There are, of course, many points in the structure of the two groups that are correlated with the development of the toes; thus, in the first group there are never any horns developed on the parietal bones, and the horns are never paired, but there are horns developed on the median line on the nasal bones, as in the rhinoceros. There is no living form of the *Perissodactyla* that ruminates; there is a characteristic number of dorsal vertebræ for each group; the astragalus of the two groups has a very different form, and there is always a third trochanter on the femur of the odd-toed forms.

Osborne, in Part I of his memoir on the Extinct Rhinoce-

roses, has given perhaps the best summary of the position of these forms. He says: "The Perissodactyla may be primarily divided by the fundamental pattern of their upper grinding teeth into four superfamilies, as follows:

1. TITANOTHEROIDAE: including the single family (1) *Titanotheridæ*.

2. HIPPOIDEA: including the two families (2) *Equidæ* and (3) *Paleotheridæ*.

3. TAPIROIDEA: including the two families (4) *Tapiridæ* and (5) *Lophiodontidæ*.

4. RHINOCEROTOIDEA: including the three families (6) *Hyracodontidæ*, (7) *Amynodontidæ*, and (8) *Rhinocerotidæ*.

To these should be added:

5. CHALICOTHEROIDEA, an aberrant superfamily, with molar teeth related to the Titanothere pattern, and perissodactyl feet provided secondarily with claws.

The eight families, in the order named, may be imagined as the contemporary branches of the four superfamilies, these in turn having branches from a still unknown Perissodactyl stem form — probably a Cretaceous member of the Condylarthra.

These eight families, familiarly known as the Titanotheres, Horses, Paleotheres, Tapirs, Lophiodonts, Hyracodonts, Amynodonts, and Rhinoceroses, when regarded as a series, present upon the one side close resemblances, or perhaps affinities, to the Artiodactyla, and an extreme departure from the Artiodactyla on the other. Thus the Titanothers exhibit many resemblances to the Artiodactyls, while the Rhinoceroses exhibit none at all, and are in many respects the most typical Perissodactyls.

Superfamily RHINOCEROTOIDEA, or Rhinocerotine group. The three distinct families included in this division may be popularly known as the Cursorial or Upland Rhinoceroses, the Aquatic Rhinoceroses, and the True or Lowland Rhinoceroses. They are briefly distinguished as follows:

Hyracodontidæ: cursorial rhinoceroses; *Hyrachyus* and *Hyracodon;* manus functionally tridactyl; upper and lower incisors and canines persistent and uniformly developed.

Amynodontidæ: Aquatic Rhinoceroses; *Amynodon* and *Cadurcotherium;* manus functionally tetradactyl; incisors atrophied; upper and lower canines greatly enlarged.

Rhinocerotidae: True Rhinoceroses; *Aceratherium* and *Rhinoceros;* manus functionally tridactyl; upper canines atrophied; median upper incisors and lower canines opposed and irregularly developed.

Our knowledge of the three divisions of this superfamily extends back only to the Middle Eocene of America and Europe, namely, to the Bridger and the somewhat older Egerkingen Beds of Switzerland. No Rhinoceroses of any kind have as yet been found contemporary with the primitive Horses and Tapirs of the Wasatch of America or the Suessonian of France, but they will undoubtedly be discovered in these or older rocks either in America or Europe, with characteristics as sharply defined as those of the other perissodactyl families.

Certainly before the Middle Eocene of North America, the Rhinocerotoidea had here or in some unknown region specialized and diverged into the three above-mentioned families, which some authors place in the single family Rhinocerotidæ. While it is quite possible that in the Wasatch or Suessonian period this group consisted of a single family, in the Bridger we certainly find two distinct families, the Hyracodontidæ and Amynodontidæ, and in the White River these coexist with the Aceratheriinæ, or ancestral true Rhinoceroses. The members of each family were evidently as widely different in their external form as in their dental and skeletal structure. . . . .

There is no doubt, therefore, that as a matter of taxonomic clearness as well as of phylogenetic fact it is best to consider these three families as entirely separate and undergoing a parallel development, probably in Europe as well as in America.

Specialization in habits.—The wide separation of these three families will be fully apparent after we have examined their chief primitive, parallel, and divergent features. Parallelism is mainly confined to the evolution of the molar teeth, for in every feature of the incisor teeth, the skull, the vertebræ, and the limbs, these

families specialized and diverged rapidly. The rhinocerotine differentiation in the broad sense of the term, imitated that of the Perissodactyla as a whole in its general functional radiation. They ran either into upland cursorial types, which competed with the Horses and the Ruminants, or into the lowland marsh or river dwellers, which competed with the Tapirs and the Titanotheres.

Among the former were the smaller, more agile, light-chested types of Hyracodonts, simultating the Miocene Horses in skeletal structure and in the development of true hoofs. Among the latter were the short, heavy types of Amynodonts, with broad, spreading, padded feet; they probably acquired, like the Tapirs, a long, prehensile upper lip, or, possibly, a true proboscis was developed, in correlation with the rather abbreviated nasals. The elevated and prominent position of the orbit would bring the eye near the surface in swimming. This feature, with the long, curved tusks, undoubtedly used in uprooting, suggests the resemblance between the habits of these animals and those of the Hippopotami. The early Aceratheres were light-limbed rather swift-footed animals, intermediate in proportions between the Hyracodonts and the Amynodonts, but far less graceful and rapid than the former, yet the destiny of this family was also to finally produce both the very slow, heavy-bodied forms, such as *Aceratherium* (*Aphelops*) *fossiger*, of the Loup Fork and the stilted, long-limbed *Aceratherium malacorhinum* of the same period.

Neither the Hyracodonts nor the Amynodonts developed horns, and all the early true Rhinoceroses had weak, hornless, nasals so that they probably appeared externally more like enlarged modern Tapirs than the well-armed animals we are now familiar with.

They did not interfere with each other because each enjoyed a different local habitat, while occupying the general geographical regions. The Hyracodonts dwelt in the drier grassy plains. The Amynodonts frequented the river and lake borders. Up to the time of the extinction of these two related families, the true

Rhinoceroses maintained a somewhat uniform structure, both in Europe and America, differing, so far as we know, in size rather than in proportions. Their dentition and their feeding habits were probably similar to those of the *R. bicornis* of Africa and the *R. sondaicus* and *R. sumatrensis* of Asia, namely, upon leaves, shrubs, and softer herbage. After the extinction of the rival families, however, there was naturally a tendency on the part of the true Rhinoceroses to enter the peculiar local habitats previously occupied by the Hyracodonts and the Amynodonts, and they accordingly diverged into upland and lowland, short and long-limbed, brachydont and hypsodont types.

Geological and geographical distribution.—(1) The Hyracodontidæ, including *Hyrachyus*, *Triplopus*, and *Hyracodon*, are very abundant, displaying a great range of size in the Middle Eocene and Oligocene of North America, and are possibly represented in the Eocene of Europe by species which have been mistakenly referred by Rutimeyer and others to *Lophiodon*. (2) The Amynodontidæ are known from the Upper Eocene or Washakie and Uinta Beds of North America, and are also possibly represented by species referred to *Lophiodon* in the Eocene of Europe, although it is difficult to determine this from the teeth alone; the latest American type is *Metamynodon* of the Oligocene, but *Cadurcotherium* represents a later and probably final stage of development in the Oligocene and Lower Miocene of France. (3) The Rhinocerotidæ are first doubtfully known in the Upper Eocene of Europe, then suddenly appear in abundance in the Lower Oligocene. They are grouped in four subfamilies. (1) Aceratheriinæ of Europe and America. These hornless types ranged through all the Miocene of North America, and then apparently became extinct upon this continent, but in Europe they extended into the Pliocene, and in Asia into the Middle Pliocene. (2) The Diceratheriinæ, or pair-horned types, have been found only in the Lower and Middle Miocene of North America and Europe. (3) The earliest Rhinocerotinæ, or Rhinoceroses possessing median horns, branched off from the Aceratheres in the Middle Miocene of Europe; they divided into three sub-

series which are scattered widely over Europe, Asia, and Africa, and displayed a remarkable specialization. (4). The most aberrant family is the Elasmotheriinæ, thus far found only in the Pleistocene of Siberia."

DISTRIBUTION TABLE, AMERICAN HORIZONS.

	Lower Eocene *Wasatch*	Middle Eocene *Bridger*	Upper Eocene *Uinta*	Oligocene *White River*	Lower Miocene *John Day*	Upper Miocene *Loup Fork*
I. HYRACODONTIDÆ.						
Hyrachyinæ						
Hyrachyus	.....	×				
Colonoceors	.....	×				
Triplopodinæ.						
Triplopus	.....	.....	×			
Hyracodontinæ						
Hyracodon	.....	.....	.....	×		
II. AMYNODONTIDÆ						
Amynodon	.....	×				
Metamynodon	.....	.....	.....	×		
Cadurcotherium[1]						
III. RHINOCEROTIDÆ						
Aceratheriinæ	.....	.....	.....	×	×	×
Diceratheriinæ	.....	.....	.....	.....	×	
Rhinocerotinæ.						

The superfamily TITANOTHEROIDÆ, with the single family *Titanotheridæ* is generally divided into two subfamilies, the *Paleosyopinæ* and the *Titanotherinæ*. The group seems to have developed in the later Eocene time, and to have reached its greatest development in the Miocene near the middle of which time it disappeared. Starting with forms about the size of the Tapirs of modern time the animals gradually increased in size until at the time of their extinction they had reached elephantine proportions. In general appearance they must have been similar to the Tapirs, with a broad, heavy body, stout limbs and a long upper lip. The brain cavity was small, and the brain was probably devoid of deep convolutions. The group reached by far its greatest development in North America, but a few forms have been discovered in the Upper Eocene and the Lower Mio-

[1] Phosphorites of Quercy.

cene beds of Europe. The two subfamilies differed chiefly in the larger size and the more complex dentition and foot structure of the *Titanotherinæ*.

Paleosyops is the most characteristic member of the first subfamily. It is found in the Lower and Middle Eocene of North America (Wind River and Bridger). The dentition was complete, that is, the incisors and premolars were all present; the premolars were simpler than the molars; the skull was without horns and without the concave outline of the upper surface that is so apparent among the Titanotheres. One species was about six feet long and three feet high.

Diplacodon from the Upper Eocene of the United States, Uinta, is of great interest in that it is in many characters related to the Rhinoceroses, and at the same time stands as an almost perfect connecting link between *Paleosyops* of the Lower Eocene and the Titanothers of the Miocene.

Titanotherium was a large form confined to the Lower Miocene and reaching its greatest development in the United States; a few specimens have been found in Europe. Despite the rather short time in which the animal lived upon the earth it developed an astonishing degree of variability, with the result that it has probably received as many different names as any form known. Thirteen genera and thirty-one species have been described from what Osborne, after a careful study of the cranial characters, regards as "one or possibly two genera, and about fourteen definable species." The Titanotheres are characterized by the development of a pair of horns on the anterior portion of the snout; the gradual loss or the tendency to the loss of the incisor teeth; the complex dentition, in which the premolars are as complex as the molars and the increased size. The largest species reached a length of between twelve and fifteen feet and a height of about seven feet. Remains are known from a large number of regions in the United States and Canada, showing that the animal roved over a wide territory.

E. C. Case.

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SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

TODD[2] maps and gives a general description of the geology of South Dakota. Archean[3] rocks are present in the Black Hills, near Sioux Falls, and near Bigstone Lake in the eastern part of the state.

In the Black Hills the Archean rocks are slates and schists, intruded by granite. The metamorphic effects in the slates and schists become more pronounced as the contact with the granite is approached. Following Van Hise, it is believed that their metamorphism was largely brought about by the intrusion of the granite. The thickness of the slates and schists is from 10,000 to 100,000 feet. In age they are believed to correspond to the Lower Huronian of the Lake Superior region. The granites, while younger than the slates and schists, are still pre Cambrian.

The Sioux quartzite is similar to the quartzite of Baraboo and the Chippewa valley, of Wisconsin, and, following Irving and Van Hise, it is believed to be of Upper Huronian age.

Near Bigstone Lake are exposures of granites, probably of Laurentian age.

All the Archean rocks are overlain unconformably by Cambrian rocks which in general dip away from the Archean exposures.

KEYES[4] gives the result of an examination of the Sioux quartzite. Impressions were seen at several points in the bedding planes of the quartzite which so much resembled those of lamellibranchs of the Cardium and Cytherea types, that, notwithstanding strong pre-conceived notions of the ancient age of the Sioux rocks, faith in their old age was very much shaken. It is concluded that the Sioux formation should be considered as pre-Cambrian until indisputable evidence to

[1] Continued from p. 753, Vol. VI, JOUR. GEOL.

[2] A preliminary report on the geology of South Dakota, by J. E. TODD. South Dakota Geol. Survey, Bull. No. 1, 1895, pp. 172. With map.

[3] Archean is used to designate the pre-Cambrian.

[4] Opinions concerning the age of the Sioux quartzite, by C. R. KEYES. Proc. Iowa Acad. Sci. for 1894, Vol. II, 1895, pp. 218–222.

the contrary is produced, but that there now exist certain doubts concerning the accuracy of this view.

Keyes,[1] in an account of the characteristics of the Ozark Mountains, briefly describes the Archean and Algonkian rocks of the region. Archean rocks occur at the east and west ends of the Ozark uplift. The best known of the areas is the eastern one, the Iron Mountain district of southeastern Missouri. Here the largest areas occur in the vicinity of the peak from which the district takes its name, and other smaller areas are scattered over a considerable range of adjacent territory. The Archean rocks in the Iron Mountain district are granites and porphyries, the latter predominating, both of which are broken through in numerous places by basic intrusives.

At the western end of the Ozark uplift, in Indian Territory, are Archean rocks, principally granites, of which there are many varieties, cut, as in southeastern Missouri, by dikes of basic material.

Immediately overlying the Archean in a number of places are beds of conglomerates and slates provisionally referred to the Algonkian. These appear to best advantage on Pilot Knob.

Haworth[2] describes and maps the pre-Cambrian geology of the area of the Iron Mountain sheet in southeastern Missouri, which covers portions of Iron, St. Francois, and Madison counties. The pre-Cambrian rocks are crystalline, massive, Archean rocks, and crystalline, stratified, Algonkian rocks.

The Archean rocks in general form the uplands. They may be divided into two general classes, basic eruptives and acid eruptives, including granites and porphyries.

The basic eruptives, of remarkably uniform character, occur principally in the southeastern part of the area, usually in dikes cutting through the granites and porphyries, but in a few cases in the form of bosses almost circular in outline. The general trend of the dikes is northeast-southwest.

The granites occur mainly in two large areas, though they are found occasionally in small patches within the porphyries. The two

[1] Characteristics of the Ozark Mountains, by C. R. KEYES. Rept. Missouri Geol. Survey, Vol. VIII, for 1894, pp. 317–352. 1895.

[2] Report on the Iron Mountain sheet — the Archean rocks, by ERASMUS HAWORTH. Rept. Missouri Geol. Survey, Vol. IX, 1896, pp. 15–27. With Sheet No. 3.

areas are the Graniteville and Stout's Creek or St. Francois areas. The porphyries occur in numerous large, uniformly distributed areas, making up nearly half the area of the entire sheet. They include what have been called by other writers quartz-porphyry, feldspar-porphyry, felsite, felsophyre, and orthophyre.

Numerous observations show gradations between the granites and porphyries, and it is concluded that the granite and porphyries were formed from the same or similar magmas, and that their difference in texture is due to crystallization under different conditions.

Algonkian rocks are found near the center of the area, capping the Archean rocks of Pilot Knob. They comprise conglomerates and slates, chiefly the former, and include the iron ore deposits of the locality. The pebbles of the conglomerate are mostly derived from the porphyry. The matrix is a fine felsitic mass mixed intimately with varying amounts of hematite. In places the ore forms almost the entire body of the rocks.

Paleozoic rocks unconformably overlie the crystallines, and dip away from the Archean hills.

Keyes and Haworth[1] describe and map the geology of the Mine Le Mot sheet, which includes portions of Ste. Genevieve, Madison, and St. Francois counties, Missouri. Archean rocks, described by Haworth, occupy about half of the area of the sheet, forming the nucleus about which later formations are exposed in concentric belts. They are granites and porphyries, cut by dikes of diabase. The acid rocks greatly predominate, the granite making up fully nine tenths of the eruptives of the area. The porphyry appears to be the surface facies of the granite, and seems to graduate downward into the latter. This is shown where erosion has been great, and has left high granite hills which are often capped by porphyry.

Cambrian rocks directly overlie the Archean rocks, with unconformable relations.

Keyes,[2] considers the granites and porphyries in the eastern part of the Ozarks. Agreeing with Haworth, he finds the granites

[1] Report on the Mine Le Mot sheet -- General geology, by C. R. KEYES; Archean geology, by C. R. KEYES and E. HAWORTH. Rept. Missouri Geol. Survey, Vol. IX, 1896, pp. 14–44. With Sheet No. 4.

[2] Geographic relations of the granites and porphyries in the eastern part of the Ozarks, by C. R. KEYES. Bull. Geol. Soc. Am., Vol. VII, 1896, pp. 363–376. Pl. 17.

and porphyries to be different facies of the same magma. Further agreeing with Haworth, he finds that the granite occupies the lower ground, the porphyries the higher ground, and that, where there are gradations between the two, the granites are at the base of the hills while the porphyries are at the top, with transition zones between. The granites occupy a comparatively small area in the northeastern part of the district. This is an area of low elevation and near the Mississippi River, and distribution is explained as due to differential erosion. The physiography of the district is discussed, and the conclusion is reached that the crystalline rocks have undergone very considerable erosion since Cambrian time. Agreeing with Van Hise, it is held as probable that the granites and porphyries are of Algonkian age. A deep boring near Kansas City at a depth of 2500 feet penetrated black foliated mica-schist, which has the characteristics of the Archean rocks.

Keyes,[1] in connection with a description of the clay deposits of Missouri by Wheeler, briefly discusses their geological occurrence. Most of the ore-bearing conglomerates of Pilot Knob and vicinity, heretofore called Algonkian, are believed to be Cambrian. The granites and quartz-porphyries of the region are not really of Archean age, as generally considered, but are probably Algonkian. In chemical, mineralogical, and structural characters, and in absence of dynamic effects, they differ from the gneissic and schistose rocks which have been reached in deep drill holes, and, therefore, they are believed to be younger than such gneissic and schistose rocks (which, it may be inferred, are believed to represent the Archean).

The geological conditions of the crystalline rocks are unfavorable to clay deposits.

Comment.— No reasons are given for the belief that the ore-bearing conglomerates of Pilot Knob are Cambrian rather than Algonkian. Until adequate reasons are presented, the conclusion of Haworth, Van Hise, and other workers in the field, that the rocks are Algonkian, must be presumed to be correct.

McConnell[2] reports on an exploration of the Finlay and Omenica

[1] Clay deposits, by H. A. WHEELER — Chapter on the geological occurrence of clays, by C. R. KEYES. Missouri Geol. Survey, Vol. XI, 1896, pp. 36–37.

[2] Report on an exploration of the Finlay and Omenica rivers, by R. G. MCCONNELL. Ann. Rept. Geol. Surv. of Canada, for 1894, Vol. VII, Part C, 1896, pp. 40.

rivers in the Rocky Mountains of western Canada. The Archean[1] rocks of the district consist of a series of well foliated mica-gneisses, mica-schists, hornblende- and actinolite-schists, quartzose schists, and crystalline limestones. The rocks of the series are usually evenly bedded, and conform in dip to the overlying formations. To the series the local term Shuswap is applied.

Shuswap rocks are found on both sides of the Finlay River, from its mouth up to its junction with the Ingenica. North of this point the formation divides. The eastern limb follows the eastern slope of the Finlay valley northwestward to the Quadacha and for some distance beyond. It has a width of four miles at Paul's Branch, where it forms the most westerly range of the Rocky Mountains. This width decreases towards the north and increases to the south. The western limb bends away from the Finlay above the Ingenica, but crosses it again at the great bend which the Finlay describes after leaving the Rocky Mountains, and continues on to the north. The width of this band was not ascertained, as its western boundary was not reached.

Another area of Shuswap rocks, separated from the first by a band of limestones, occurs on the Omenica River above the Oslinca. The band has a width of ten miles.

The Shuswap series is overlain by Lower Paleozoic strata.

Peale[2] maps and describes the geology of the Three Forks quadrangle of Montana. Archean gneisses and Algonkian sediments occupy large areas. The Archean gneisses occur principally in the foothills of the Bridger range, the mountain masses at the northern and southern ends of the Madison range, west of the Madison valley and north of Virginia City, the southern part of the Jefferson range, the foothills of the Gallatin range, south of the Gallatin valley, and beneath the Bozeman Lake beds at the southern end of the plateau, between the Gallatin and Madison valleys. The rocks referred to the Archean may possibly include some that eventually may be referred to the Algonkian. The contacts of the Archean with the overlying sedimentaries are, in all cases, unconformable.

The Algonkian series comprises two divisions, the Cherry Creek beds, and the Belt formation.

[1] In conformity with the usage of Canadian geologists, Archean is above used in the sense of pre-Cambrian.

[2] Geol. Atlas of the United States, Three Forks Folio, No. 24, by A. C. PEALE. Washington, 1896.

The Cherry Creek beds occupy an area of thirty to forty square miles in the foothills immediately west of the Madison River and a few miles north of the southern boundary of the quadrangle, and also a small area on the east side of the Madison valley, at the western edge of the Madison range. The rocks are marbles and interlaminated mica-schists, quartzites, and gneisses. Between Cherry Creek and Wigwam Creek, on the west side of the Madison valley, Cambrian strata rest unconformably upon the upturned edges of the Cherry Creek beds. Before the deposition of the Belt formation, the Cherry Creek beds suffered extensive deformation.

The Belt formation occurs in the northern portion of the district —in the foothills of the northern portion of the Bridger range, in the hills north of the Gallatin and East Gallatin rivers, and in the rugged hills of the Jefferson canyon. In the lower portion of the formation are coarse sandstones and conglomerates, in the central part appear argillites and siliceous limestones, and in the upper part sand stones predominate. The Belt formation is overlain by the Flathead (Cambrian) quartzite. It is possible that further investigation may result in the reference of this formation to the lower part of the Cambrian. At present, however, it is referred provisionally to the Algonkian.

The Flathead and Gallatin formations (Cambrian) rest with marked unconformity upon the Archean for three fourths of the district; for the remainder of the district they rest upon the Algonkian, and the unconformity, if it exists, is very slight.

Weed and Pirsson map[1] and describe the geology of the Castle Mountain mining district of Montana. The Belt group of rocks, assigned to the Algonkian, occupies large areas in the district. The series presents no definite lithological horizons, but there is a general sequence, from the base upward, as follows:

Alternating shales and sandy beds.
Dark gray, laminated, thinly-bedded limestone.
Pearl-gray sericitic shales.
Sandy shales, with thin beds of ripple-marked sandstone.
Red shales and slates.

The series has thus far yielded no fossils. It attains a thickness of 8000 feet. Basic and acid intrusive rocks penetrate the Belt formation very freely.

[1] Geology of the Castle Mountain mining district, Montana, by W. H. WEED and L. V. PIRSSON. Bull. U. S. Geol. Survey, No. 139, 1896, pp. 165. With geol. map.

At many localities the Belt series is seen to be in conformable relations to overlying fossiliferous rocks of Cambrian age, the Flathead and Gallatin formations, and, while assigned to the Algonkian, the series is spoken of as forming the lower part of the Paleozoic of the area.

Comment.— It is unfortunate that rocks assigned to the Algonkian should be spoken of as forming the lower part of the Paleozoic, even though the Belt series may be a downward conformable extension of the Paleozoic. If properly Algonkian, *i. e.*, sedimentaries and equivalent igneous rocks below the Olenellus horizon, whether conformable or not, if referred to any era, they should be referred to the Proterozoic.

Weed and Pirsson[1] briefly describe the geology of the Little Rocky Mountains of central Montana. The core of the mountains is formed of crystalline schists, of which the type most usually seen is a black glistening amphibole-schist, or amphibolite. In the saddle west of Shellrock Mountain, the series consists of amphibole-schists and mica-schists, pink gneiss, and white quartzites, the various rocks occurring in rapidly alternating beds but a few feet thick.

The crystalline schists are overlain by Cambrian sedimentaries. Intruded between the schists and sedimentaries is a great laccolithic body of granite-porphyry.

The presence of the quartzite is taken as indicating the Algonkian age of the crystalline series. However, similar schists occurring in Montana have been generally classed as Archean, and these rocks are metamorphosed and quite unlike the slightly altered Belt Mountain Algonkian series. The crystallines are, therefore, not definitely assigned to either the Archean or Algonkian.

Hague, Weed, and Iddings[2] map and describe the geology of the Yellowstone National Park, Wyoming. Archean rocks are found near the borders of the district in the mountain ranges which encircle the Park plateau. They comprise granites, gneisses, and schists. The granites and gneisses are for the most part coarsely crystalline, and the entire series shows the effect of metamorphism by pressure.

Algonkian rocks are recognized only in the southern end of the

[1] The geology of the Little Rocky Mountains, by W. H. WEED and L. V. PIRSSON. JOUR. GEOL., Vol. IV, 1896, pp. 399–428.

[2] Geol. Atlas of the United States, Yellowstone National Park Folio, No. 30, by ARNOLD HAGUE, W. H. WEED, and J. P. IDDINGS. Washington, 1896.

Park, and are best exposed on the southern slope of Mount Sheridan, from which the formation has been called the Sheridan quartzite. The Sheridan quartzite formation comprises sandstones and slates, which contain no fossils. Unconformably overlying the Sheridan quartzite is the Ellis (Juratrias) limestone. The assignment of the formation to the Algonkian is based largely on the fact that similar rocks are unknown in the Paleozoic series, and on the fact that no sedimentary rocks older than these quartzites are exposed in this district.

Hague,[1] in a discussion of the age of the igneous rocks of the Yellowstone National Park, mentions the occurrence of rocks of Archean age in the surrounding mountain ranges. The Tetons, bordering the park to the south, consist mainly of an Archean mass, which towers high above all later rock formations. In the Absaroka range, stretching along the entire east side of the park, and formed mainly of igneous rocks, granite and schists are exposed at the northern end. The Snowy range, which shuts in the park to the north, is largely made up of Archean schists, gneisses, and granites, associated with the more recent outbursts of lava. In the Gallatin range, on the west, a body of crumpled gneisses and schists forms the nucleus of the mass. The Archean masses formed either a part of a broad continental mass, or a group of closely related islands. Resting unconformably upon the Archean are great thicknesses of Paleozoic and Mesozoic rocks.

Eldridge[2] gives an account of a geological reconnaissance across Idaho, on a northeast line through Boisé and Salmon City. Rocks are found which are provisionally referred to the Archean and Algonkian. To the Archean are referred granite and gneiss, which have their greatest development in the mountains of the western part of the state, but which are also widely exposed elsewhere. In places in the granite and gneiss are included bands of calcareo-micaceous or quartzitic slates, and in these cases the reference of the rocks to the Archean, instead of the Algonkian, is questionable. To the Algonkian is provisionally assigned the great series of micaceous, quartzitic, and chloritic schists of eastern Idaho. The reference is based merely upon

[1] The age of the igneous rocks of the Yellowstone National Park, by ARNOLD HAGUE. Am. Jour. Sci., 4th ser., Vol. I, pp. 445–457, 1896.

[2] A geological reconnaissance across Idaho, by GEORGE H. ELDRIDGE. Sixteenth Ann. Rept. U. S. Geol. Surv., Part II, 1895, pp. 217–276.

lithological character, and the resemblance to other beds in the Cordilleras which have already been so assigned. The Algonkian series in areas of strong development has a probable thickness of 3000 to 4000 feet. It is believed to be unconformable with the underlying granite.

Cross[1] describes the geology of the Cripple Creek district of Colorado. The account of the general geology is substantially the same as that previously given by Cross for the Pike's Peak quadrangle,[2] of which the Cripple Creek district is a part. Granites and gneisses occupy a large area in the district. Included in these granites and gneisses are large and small fragments of quartzite, quartz-fibrolite-schist, quartz-mica-schist, and other similar rocks. It is believed that the quartzite fragments belong to a great series of pre-Cambrian (Algonkian) sediments. Hence the granites including such fragments are not Archean; but they are older than the only Cambrian rocks as yet identified in Colorado, and they are therefore mapped as Algonkian. The schists are probably also sedimentary, but it is quite possible that some, if not all, have been produced from Archean gneisses forming the foundation upon which the Algonkian sediments were laid down.

Emmons, Cross, and Eldridge[3] describe and map the geology of the Denver basin in Colorado. Pre-Cambrian rocks form the mass of the Colorado or Front Range along the western border of the Denver Basin, later formations resting against the flanks of the mountains. In the lower canyons of South Boulder and Coal creeks, are beds of highly altered quartzite and conglomerate, associated with schists, aggregating a thickness of 1000 feet, which occupy a position between Triassic sandstones and the gneisses of the interior of the range. These are undoubtedly sedimentary and are probably of Algonkian age. In passing from these sedimentaries westward toward the center of the range there appear successively gneisses, granite-gneisses, and massive granite. As the areas occupied by the granites and sedimentaries have not been definitely delimited, and as the sedimentaries

[1] General geology of the Cripple Creek district, Col., by WHITMAN CROSS. Sixteenth Ann. Rept. U. S. Geol. Surv., Part II, 1895, pp. 13–109.

[2] Reviewed in this JOURNAL, Vol. IV, 1896, p. 371.

[3] Geology of the Denver Basin in Colorado, by S. F. EMMONS, WHITMAN CROSS, and G. H. ELDRIDGE. Mon. U. S. Geol. Surv., No. XXVII, 1896, pp. 556. With maps.

occupy but a small proportion of the pre-Cambrian area, the sedimentaries are not mapped as Algonkian, but, with the granites, are mapped as pre-Cambrian.

Osann[1] gives the geology and petrography of the Apache (Davis) mountains of western Texas. The oldest rocks found therein are the crystalline schists, which composed the greater part of Carrizo and Van Horn mountains. Here is found a great set of coarsely crystalline gneiss, mica-schist, and associated schistose rocks. These have in general a parallel northwest-southeast strike, which agrees with the axis of the range. Following Professor von Streeruwitz, these are placed with the fundamental rocks.

Sapper[2] describes the geology of Chiapas, Tabasco, and the Peninsula of Yucatan, and mentions the occurrence of Azoic rocks in the Sierra Madre Mountains. These rocks include gneiss, mica-slates, and phyllites. A band in the first northern range of the Sierra, near the plantations of Piedad and San Vincente, trends N. 7° W., and dips 5° to the N.E. Among the bowlders washed down by the Aguacate River may be seen gneiss, mica-slates, and phyllites, which indicate the presence of the crystalline formations also in the interior of the Sierra Madre.

Comment.— The term Azoic is used in a very indefinite way. It apparently is applied to all ancient crystallines, both sedimentary and igneous, and is not necessarily confined to the pre-Cambrian. However, the term is placed as a subheading under sedimentary formations, indicating, possibly, that ancient sedimentaries only are included.

Ells[3] reports on the geology of a portion of the Province of Quebec comprised in the southwest sheet of the eastern townships map (Montreal sheet), and describes pre-Cambrian rocks occurring to the east of the St. Lawrence River. These occur along the axis of the Sutton

[1] Beiträge zur Geologie und Petrographie der Apache (Davis) Mts., West-Texas, by A. OSANN. Min. und Pet. Mitt., Bd. XV, Heft 5, 6, 1896, pp. 394–456, mit Tafeln XI–XII, Fig. im Texte.

[2] Geology of Chiapas, Tabasco, and the Peninsula of Yucatan, by C. SAPPER. JOUR. GEOL., Vol. IV, pp. 938–947, 1896.

[3] Report on a portion of the Province of Quebec, comprised in the southwest sheet of the "Eastern Townships" map (Montreal sheet), by R. W. ELLS. Ann. Rept. Geol. Surv. of Canada, for 1894, Vol. VII, Part J, 1896, pp. 1–92.

Mountain range, and in the anticline east of Memphremagog Lake near Fitch Bay.

The crystalline schists of the Sutton Mountain range may be divided into two principal portions, viz., the gneissic, micaceous, quartzose, and talcose schists of the central portion or that in which the axis of the anticline is situated, and a series of green, chloritic, schistose rocks, with the characters of altered dioritic rocks, constituting an easily separable portion, flanking the central area of schists to the west, and extending from the Vermont boundary to the St. Francis in the vicinity of Richmond. This second or chloritic division is recognized also at various points on the eastern slope of the range, but it does not there present so marked a development. The age of the green schistose, dioritic portion is doubtful, but it appears to coincide to some extent with the Volcanic Group of Selwyn,[1] which he supposed to be probably Lower Cambrian or Huronian.

East of Memphremagog Lake, near Fitch Bay, the pre-Cambrian rocks are schistose, altered, dioritic rocks, occasionally with micaceous bands, and often containing clear grains of quartz. These rocks are apparently allied to the green chloritic schists of the west slope of the Sutton Mountain range, and are placed on the map as doubtfully Huronian.

Cutting the pre-Cambrian rocks, and possibly also later sediments, are a considerable variety of rocks, such as granites, syenites, diorites, diabases, serpentines, traps, etc., evidently of different ages. It is probable that the age of the granites is not far from the close of the Silurian period.

Adams[2] describes and maps the Laurentian area north of the St. Lawrence River, in the northwest corner of the southwest sheet of the "Eastern Township" map (Montreal sheet). This Laurentian area is a portion of the southern margin of the great northern Canadian area of Laurentian rocks. The area is about equally divided between the rocks of the Laurentian system and intrusions of anorthosite which break through them. The Laurentian[3] consists of red and gray ortho-

[1] Stratigraphy of the Quebec Group and the older crystalline rocks of Canada, by A. R. C. SELWYN. Rept. Geol. Surv. of Can., for 1877–8, Part A, p. 3.

[2] Laurentian area in the northwest corner of the Montreal sheet, by F. D. ADAMS. Supplementary chapter to Ell's report on a portion of the Province of Quebec. Ann. Rept. Geol. Surv. of Canada for 1894, Vol. VII, Part J, 1896, pp. 93–112.

[3] The term Laurentian is thus used as it was by Logan.

clase gneisses, presenting great variations both in structure and composition, with which are associated crystalline limestones, quartzites, and amphibolites. In certain parts of the area two divisions can be recognized in the Laurentian: an upper series, characterized by the presence of crystalline limestones, quartzites, and gneisses of sedimentary origin with a banded structure, called the Grenville series; and a lower series of gneisses in which no limestone, etc., occur, and which possess a foliated rather than a banded structure, known as the Fundamental Gneiss. Grenville rocks are recognized south of Rawdon and in the westerly portion of the St. Sauveur district. The Fundamental Gneiss apparently occupies much of the St. Jerome district. However, it has been found impossible to separate the two series and delimit them on the map.

The composition of most, if not all, of the gneisses belonging to the Fundamental Gneiss can be paralleled among the igneous rocks, and it is concluded that many of these gneisses, at least, were of igneous, probably of intrusive, origin. In the Grenville also some of the gneisses are of igneous origin. However, many are believed to be of sedimentary origin, for the following reasons: (1) they are associated with numerous and heavy beds of limestones and quartzite; (2) they have a prevailing banded character, accompanied by a very extensive recrystallization; (3) graphite is of frequent occurrence in them; (4) chemical analyses show that they have the composition, not of igneous rocks, but of sedimentary sands and muds.

The quartzite is sometimes pure, but frequently holds garnet, sillimanite, or other minerals. The limestones are coarsely crystalline marbles, sometimes pure, but at other times including grains of quartz, pyroxene, phlogopite, graphite, and other minerals.

The anorthosite belongs to the gabbros, but is characterized by the great preponderance of plagioclase feldspar, which is often so abundant as to make up the entire rock. At its contact with the gneisses are many contact phases. The anorthosite has been squeezed and foliated, together with the gneisses which it cuts, and it is concluded that its intrusion antedated at least the termination of the great earth movements which affected the Laurentian in pre-Potsdam times. In proportion as the anorthosites exhibit granulation they become light colored, some of the most metamorphosed ones resembling marble in appearance, although chemically they do not differ from the less modified anorthosites.

On the upturned edges of the Archean rocks, both gneiss and anorthosite, the Potsdam sandstone and other Cambro-Silurian rocks repose in flat and undisturbed beds.

Ells and Barlow[1] describe the physical features and geology of the proposed Ottawa Canal between the St. Lawrence River and Lake Huron. The proposed canal for several hundred miles traverses for the most part Archean rocks nearly at right angles to the strike of their schistosity or banding. The work of Logan, Murray, Lawson, and Adams, and others of the important workers on the Canadian crystalline is briefly summarized.

The Grenville series of the Original Laurentian area probably illustrates the most perfect section of Laurentian rocks which we can yet recognize. This section shows various kinds of gneisses, foliated and stratified, with foliated and massive granites and syenites, pyroxenic, dioritic, hornblendic, and quartzose rocks, and quartzite and limestone. In the basal beds of the limestone and quartzite, supposed to constitute the upper member of the series, are interstratified bands of rusty quartzose gneiss, which from the available evidence is believed to form an integral part of the limestone series. This portion presents in its banded arrangement of quartzose and calcareous rocks, the usual aspect of true altered sedimentary strata. The same well banded arrangement is also visible in some of the directly underlying gneiss; but in the case of the great mass of this gneiss, the microscopic examination shows the evidence of an aqueous origin to be wanting. Some portions of the igneous rocks are undoubtedly older than the limestones, and most probably represent the lowest portions of the earth's crust known to us. Other portions are clearly established to be of more recent age than the crystalline limestone. The oldest gneisses are foliated, rather than stratified, but in their foliation they underlie the regular series of stratified hornblende and other gneisses which occur frequently between the fundamental gneiss and the crystalline limestone and quartzite series at the summit of the section. To this fundamental series may be assigned the rocks of Trembling Mountain, those forming the anticlinals north of Lachute, rocks from various places throughout the Grenville district, and large areas at

[1] The physical features and geology of the route of the proposed Ottawa Canal between the St. Lawrence River and Lake Huron, by R. W. ELLS and A. E. BARLOW. Proc. and Trans. Roy. Soc. of Canada, 2d ser., Vol. I, Sec. IV, 1895, pp. 163–190. With sketch map.

different places along the Upper Ottawa River section. Concerning many of the intermediate gneisses, it may be said that while in their general aspect they resemble stratified sedimentary rocks, their study under the microscope shows them to have presumably a different origin, so that it is possible that the true altered aqueous portion may be confined to the areas of crystalline limestone with their associated bands of quartzite and grayish quartzose and hornblende gneiss. The crystalline limestones are particularly developed along the Ottawa River section, from the vicinity of Deschenes Lake, west of Ottawa city, to the village of Bryson, in which section they are frequently cut by large areas of granitic and dioritic rocks. At one place, near the Chats, the limestone is overlain by a considerable breadth of Huronian-looking schists, etc., which have been described under the name of Hastings series. The limestone has its most westerly outcrop on the Ottawa in the vicinity of Coulonge Lake, a short distance west of the Black River. From here west to the mouth of the Mattawa the limestone occurs as separate belts occupying synclinals in the upper stratified gneisses.

The rocks along the route of the Mattawa and French Rivers to Lake Huron are chiefly those which have been regarded as Laurentian gneisses. There is very little of the crystalline limestone which forms such an abundant constituent of the Laurentian farther east, and this, as well as the apparent inferior position of the gneisses, according to their banding, caused them early to be placed at the very base of the geological series, and called the Lower Laurentian series. Crystalline limestone occurs at Talon Lake, on the east shore of the Great Manitou or Newman Island in the eastern part of Lake Nipissing, as well as on two of the small islands composing this group, and on Iron Island. All the evidence seems to point to the fact that the limestone has been caught up in the gneisses during its eruption.

The foliation of the gneisses is produced either by (1) alternation of light and dark bands, or (2) by the more or less parallel distribution of the component minerals. In many of the plutonic rocks, and particularly in the granites and similar rocks, there is a marked tendency for the bisilicates to aggregate themselves in certain belts or patches (called Auscheidungen in the granites). The result of pressure on a rock characterized by the presence of these masses would be the flattening of the dark areas into more or less lenticular areas. Again, many of the dark bands are seen to have had their

origin as dikes, which have been intruded along the planes of foliation.

Smyth[1] describes pre-Cambrian diabase dikes cutting the granites and gneisses of the Admiralty Group of the Thousand Islands, St. Lawrence River. C. K. LEITH.

[1] A group of diabase dikes among the Thousand Islands, St. Lawrence River, by C. H. SMYTH. Trans. N. Y. Acad. Sci., Vol. XXIII, 1893–4, pp. 209–214.

Reviews.

The Naples Fauna (Fauna with Manticoceras intumescens) in Western New York. By John M. Clarke. 16th Ann. Rep. N. Y. State Geol., pp. 31–165, Plates I–IX.

The faunas of the Upper Devonian period in New York, are of great interest to all students of the geologic phases of palæontology. In the earliest fauna of this period, the Cuboides fauna of the Tully limestone, there appear suddenly several new types of organisms, chiefly brachiopods, among which the most important is *Hypothyris cuboides*, which have no genetic predecessors in the region. These strangers or exotic forms, therefore, must be considered as migration species whose previous evolution had taken place in some other geologic province, but which, with the establishment of some new line of communication at the beginning of Upper Devonian time, were enabled to find their way into the New York province. By a careful study of this Cuboides fauna and its geographic distribution, Professor H. S. Williams has been led to the conclusion that it first developed in the European or Eurasian province and later migrated into North America, coming in from the northwest along the Mackenzie basin, moving southward and finally eastward into the New York province.

The Naples or Intumescens fauna, which is the subject of Professor Clarke's paper, is a successor of the Cuboides fauna in western New York. Like the latter it is a widely distributed fauna in Europe, and it is always characterized by the goniatite genus *Manticoceras* of which the species *M. intumescens* is the common European form. Outside of New York the fauna characterized by this type of goniatite is found in North America only in Iowa and in the Mackenzie basin. In these two localities the characteristic goniatite is but sparsely represented, but in western New York it is present in considerable abundance and is represented by numerous species. From the evidence, therefore, it would seem that this fauna also found its way from Europe into North America by the same path along which the Cuboides fauna had migrated, but at a little later time. Along the way it left but slight

traces, but when it reached that part of the Upper Devonian seas which is now western New York, it found a wonderfully congenial environment and blossomed out anew.

The strata occupied by the normal Intumescens fauna are those of the typical Portage series of Hall in western New York. The fauna makes its first appearance, however, in the Styliola limestone in the midst of the Genesee shale, after which it disappears during the deposition of the Upper Genesee shales, to reappear in the Portage beds. Such a preliminary appearance of a new fauna, before it becomes an established normal fauna, is called by Professor Clarke a *prenuncial* fauna. The Styliola limestone, therefore, contains the prenuncial Intumescens fauna.

Further east, in the Ithaca section, the Intumescens fauna never became the normal fauna, but there existed contemporaneously with it a fauna which was constituted in large part of a recurrence of Hamilton species. Occasionally, however, a species of *Manticoceras* wandered into this region from the west and is found associated with the Ithaca fauna.

From this relation of faunas it will be readily seen that the term Portage cannot be used both in a stratigraphic and in a faunal sense. If it is used as a faunal name it must be restricted to the Intumescens fauna, the fauna of the original Portage rocks. If it is used as a stratigraphic name to include all those strata in New York which were deposited during a given portion of Upper Devonian time, it will include at least two quite distinct faunas. For the expression of the time duration and the geographic restriction of a particular faunal province, a technical term is often needed; a term which has not only a time significance, but a geographic significance as well. For this Professor Clarke has proposed the term *Zoehemera;* thus the zoehemera of *Manticoceras intumescens* would be the time during which the Intumescens fauna existed in the restricted geographic area in which it was distributed.

Professor Clarke's paper is devoted entirely to the cephalopods of the fauna, but the reader is led to believe that the remaining classes will be discussed at an early date. Of the cephalopods thirty species and varieties are recognized, twenty-one of them being described as new. Thirteen of the forms belong to the characteristic Intumescens fauna genus, *Manticoceras*. Under the older conception of species of goniatites nearly all of these might perhaps be included in the one

general species *M. intumescens*, but with the modern methods of ontogenetic study of the cephalopods, which have been used in a most satisfactory way in conducting this investigation, specific lines are drawn with far greater precision. The ontogenetic stages of most of the species are carefully described and fully illustrated by many figures in the text, so that the paper is valuable to the biologist as well as to the geologist.

STUART WELLER.

Geological Survey of Canada, Annual Report. New Series, Vol. IX, 1896. DR. G. M. DAWSON, Director.

During the year work was done in British Columbia, Alberta, Ontario, Quebec, Nova Scotia, Labrador, and the region west of Hudson Bay.

In British Columbia Messrs. McConnel and McEvoy gave their attention to the mining region around Nelson, Trail and Rossland. Some important facts are noted regarding the occurrence of ores. A boring in the Cretaceous formation at Athabasca Landing, Alberta, was carried to a depth of 1770 feet in the hope of reaching the petroleum-bearing "tar-sands" which form part of the lowest member of that formation to the northeast. The boring had to be abandoned, but other attempts will be made.

The report of Mr. J. B. Tyrrell on his work in the unexplored region west of Hudson Bay is one of special interest. He gives an historical sketch of earlier explorations of Hudson Bay and adjacent lands, many of which were connected with the search for a "Northwest Passage." The formations observed include the Recent, Pleistocene, Silurian, Cambro-Silurian, Cambrian, Huronian and Laurentian, of which the last is by far the most extensive. Pleistocene sea beaches and terraces are found at heights of 100 to 600 feet above sea level. In several places series of four to seven terraces mark shore lines of later glacial and postglacial times. The glacial geology of the region is accorded about twenty pages of the report. Several centers of glacial outflow are noted, about 140 strial directions recorded and many eskers, drumlins, moraines and extra-glacial lakes are described. A map accompanies the report.

Dr. Bell's report on his work in Ontario consists of a correlation of reports of work done at various times on the area of the French

River sheet. A new map is issued. Dr. Adams and Mr. Barlow worked on the area of central eastern Ontario covered by the Haliburton sheet. This is a region of much importance in the determination of the relationships of the various members of the Archean, and the results of Dr. Adams' investigations when completed will throw much light on the problem. Already many important facts have been brought out. An important discovery of corundum in Hastings county is announced. The work of mapping the Rainy River gold-bearing region was continued by Mr. McInnes. Dr. Ells continued the work in the area between the Ottawa and St. Lawrence rivers.

The observations on glaciation in southeastern Quebec by Mr. Chalmers show two periods of glaciation. In the first, which appears to have been local and centered in the Notre-Dame mountains, the ice moved northward to the St. Lawrence valley. The second was the Laurentian. The bowlder clays of the two differ lithologically. Marine shore lines show changes of level amounting to 600 or 700 feet in Pleistocene times. Slight postglacial dislocations of the slates were observed in many places. Dr. Bell reports on field work in the region of the Upper Ottawa and Rupert rivers and Mistassini Lake.

Mr. A. P. Low continued his exploration in northern Labrador between Hudson Bay and Ungava Bay. The rocks are principally Archean, but considerable areas of Cambrian were found. The land was completely covered by the glacial ice-sheet. The névé region seems to have been near the present watershed. On the western slope the ice moved nearly westward veering slightly to the south. On the eastern slope its initial direction was eastward but its final direction was northward to Ungava Bay. On the western slope the eskers correspond in direction with the present drainage lines, which, however do not agree with the direction of ice movement. The unstratified drift is generally in hills of irregular form and direction. The bowlders are generally of local origin. The highest marine terrace seen on the Hudson Bay side was 710 feet above sea level while the highest on the eastern slope was 620 feet above the sea.

Dr. Bailey and Mr. Fairbault worked in the gold-bearing Cambrian region of Nova Scotia, where mining is quite active.

The Chemical and Mineralogical Report by Dr. Hoffman contains the results of many analyses and assays. The report on Mineral Statistics and Mines is very complete.

R. D. GEORGE.

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